FOREST PRODUCTS RESEARCH 1939-1947

DEPARTMENT OF SCIENTIFIC
AND INDUSTRIAL RESEARCH

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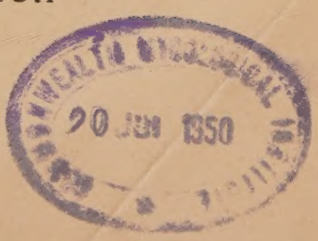

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORTS OF THE FOREST PRODUCTS RESEARCH BOARD

WITH THE REPORTS OF
THE DIRECTOR OF FOREST PRODUCTS RESEARCH

FOR THE YEARS
1939-1947

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1950

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31st December, 1947

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE PERIOD 1st JANUARY 1939—31st DECEMBER 1945

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board beg leave to present a report on our proceedings during the period 1st January, 1939 to 31st December, 1945.

As might be expected, with the war came a number of special problems for the Laboratory, which, in due course, came to occupy its attention to the exclusion of almost all its normal work. The present report is in effect a brief review of activities throughout the period of hostilities, followed by a reference to proposals made for the post-war development of the Laboratory.

One of the most serious impacts of the war upon the timber-using industries was the drastic constriction, or with respect to some species the complete cessation, of supplies of timber either as the raw material or as products. This led to a heavy dependence upon home-grown timber and such exotics as could be obtained, and this, in turn, brought in its train difficulties of seasoning, of woodworking, of conservation, and, particularly in regard to the specialized industries, of substitution. In the solution of these difficulties, the Laboratory came to play a central part. Its officers contributed their experience in the manner most appropriate for meeting the national requirements, irrespective of their normal peacetime function. We cite a few examples. One early problem was how to make good the serious loss of supplies of charcoal, which was to a considerable extent imported from Germany before the war and which is essential for the rayon, non-ferrous metal and other important industries. This was met by the portable charcoal-burning kiln developed by the Laboratory and by the Laboratory's following its development and exploitation beyond normal limits by seconding an officer to the Ministry of Supply, Timber Control Department, to supervise kiln erection, and by training operators.

A good example of work done on the conservation of supplies was the revision of the aircraft plywood specification based on special tests carried out by the Laboratory. The result was to show that the war-time aircraft industry could safely use very large quantities of material which otherwise had to be rejected, and at a time when plywood was in desperately short supply. Another example of the war-time effort of the Laboratory was the part it played in the nation-wide scheme promoted by the Timber Control Department for an improvement of kilning facilities to meet the acute shortage of kiln capacity. This scheme, which embraced the examination by the Laboratory of all new plans, the inspection of kilns, advisory work and the training of operators, made an incalculable difference to the efficiency of seasoning in this country, and was, as well, a model of smooth inter-departmental co-operation, which has been continued into the post-war period.

These, and other examples of the assistance given by the Laboratory in the general war-effort, are described by the Director in his report which is appended. It is clear that the Laboratory played a very real part in the

solution of the serious problems caused by the shortage of so important an industrial material as timber. The Director concludes his account with a reference to the advisory work. In the aggregate, this constituted, possibly, the biggest call on the accumulated knowledge of the Laboratory, and the most important service rendered by the officers, even though it does not lend itself to the singling out of individual items. It brought the Laboratory into much closer relation to the timber-using industries and made them aware, as never before, of the value of the information available at the Laboratory.

This fact was very much in our minds when, in 1943, we came to consider, at your Lordships' invitation, recommendations for the post-war activities of the Laboratory. The success of its work must depend, in the end, on the extent to which the results of its researches are applied in day-to-day practice and it is necessary that the Laboratory should be in a position to meet requests that are made to it for the advice and information which it alone can give. We considered it important therefore that steps should be taken to revive and strengthen the section which dealt with relations with industry in order to organize more effective dissemination of the results of the work and to make fresh contacts with industry. As another step in the same direction, we suggested that facilities should be provided at the Laboratory for giving advanced training to technical men from the industry. The need for such arrangements was made clear towards the end of the period under review by the many requests reaching the Laboratory for advice as to the most suitable of the available timbers for such different purposes as furniture making, coach-building, textile machinery, ship-building, plywood and cooperage, to mention but a few. It is, however, essential that these and other similar developments should not be brought about at the expense of the provision for research, which is needed to ensure a steady flow of new information. The need for adequate provision for research is made all the more compelling by the important changes in the technique of using wood to which current development points. For instance, the chemical utilization of wood is likely to make great strides in the next few decades. This calls for further development of the work on wood carbohydrates undertaken before the war. The war has also brought about more extensive use of wood in combination with synthetic resins, and this demands more research on wood-glue aggregates. Progress in the use of plywood and allied laminated products calls for extended effort and facilities at the Laboratory, including the installation of a small scale plywood factory, so that the processes involved may be better identified and studied. Again probable changes in the direction of less use of massive solid timber in all forms of construction, and the general need for economy in structural use of timber, are likely to emphasise the importance of the work on timber mechanics. At a more fundamental level, the study of the physics of timber is likely to acquire added significance as providing the wider basis of knowledge required by the future changes in the industrial use of wood. Similarly other sections, Seasoning and Bending, Wood Preservation, Wood Structure, Woodworking, Entomology and Mycology are likely to continue to have heavy demands made on them. Accordingly, we made a number of recommendations for augmenting the resources of the Laboratory in men and equipment.

We are glad to note that by the end of the period under review, certain of the more immediate needs for increased facilities at the Laboratory were already well under way. We refer to the building of the new Composite Wood Laboratory ; the conversion of the " Dry Rot " house for research on the storage, ' pot life ', and assembly technique of synthetic resins and other adhesives under various tropical conditions, and the provision of a temporary Structures Laboratory for work on timber economy in housing.

We welcomed also the evidence which was forthcoming in 1945 of a closer drawing together of the Laboratory and the industries concerned with its work. This was made manifest by the many requests for information and the number of visits by leading members of firms for discussions on their problems. We would also mention, in particular, the formation, in 1945, of an Adhesive Makers' Panel for the exploration of matters of common interest to the manufacturers and the Laboratory, and the development of the arrangements for co-operation with the Timber Development Association.

While the period under review closed with the Laboratory in the midst of the difficult transition from war-time work to that of peace-time, these extensions of the basis of mutual confidence between the Laboratory and the industry provide an excellent augury for the future.

We feel that we ought not to conclude this review without paying a tribute to Mr. W. A. Robertson who retired from the Directorship in 1945, being succeeded by the present Director, Dr. F. Y. Henderson. Mr. Robertson had been Director for twelve years and to him fell the task not only of extending and enhancing the tradition and the prestige of the Laboratory in his period of office during the years of peace, but also of having overcome the difficulties of the changeover from peace to war and of having maintained the high standard of the Laboratory's activities during the strenuous period of the war itself. Our good wishes go with him in his appointment as Forestry Adviser to the Colonial Office.

E. J. SALISBURY,
Chairman

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE PERIOD 1st JANUARY 1939—31st DECEMBER 1945

The period—1st January 1939 to 31st December 1945—covered by this report is marked by an eight-months period of pre-war work, the period of hostilities, and the eight-months period in 1945 when the main weight of the war effort of the Laboratory had been lifted, in May, by the defeat of Germany, and completely lifted in August on the surrender of Japan.

The eight-months period of pre-war work calls for no comment in this report at this distance of time, **except** to say that the results have either already found their way into the Laboratory's published reports or will do so.

The present report therefore is conveniently divided into two parts :

(i) Part I dealing with the period of hostilities when the work of the Laboratory was almost wholly devoted to war-time problems.

(ii) Part II dealing with the period May–December 1945 when the attention of the Laboratory was divided between winding up war-time work and turning over to peace-time work.

PART I. SUMMARY OF ACTIVITIES DURING THE PERIOD OF HOSTILITIES

Shortly after the outbreak of war in September, the Laboratory became immersed in war-time problems. On this account, the pre-war research programme was perforce relegated to the background to permit of *ad hoc* investigations for other government departments or for contractors working for them. This work covered a wide field on many forms of timber from branchwood and sawdust to plywood and other composite materials containing wood as a major component. Other government departments for which work was undertaken included the Admiralty, the War Office, the Air Ministry, various branches of the Ministry of Supply, including the Timber Control Department, and the Ministry of Home Security. Certain units of the United States Army also made use of the facilities offered by the Laboratory, particularly in connexion with packaging. Progress in development of new methods of utilizing timber and in enhancing its inherent properties has been rapid in the period under review and many of the results of the war-time work will undoubtedly prove valuable in industry in the post-war years.

The following is a brief review of the more outstanding features of this work.

CHARCOAL PRODUCTION IN PORTABLE KILNS

Before the war approximately half the charcoal used in the rayon, non-ferrous metal and other important industries in this country was imported, mainly from Germany. The significance of this in a war emergency had been realized and for some time previously research at the Laboratory had been directed to the design of a portable charcoal kiln and to the development of a satisfactory technique for the production of high-grade charcoal therein. By virtue of the knowledge thus obtained it was possible to expand production so rapidly that in a few months the threatened shortage was averted and all requirements could be met. An officer of the Laboratory, the late Mr. G. H.

Donald, to whom full credit for the success of the kilns is due, was seconded to the Ministry of Supply, Timber Control Department, to supervise kiln erection and to train operators.

HOME-GROWN TIMBERS

The supply of timber from the Empire and abroad was severely restricted from the beginning of the war by interruption of sea transport and other causes. To compensate in as large a measure as possible for the reduction in imported lumber, the use of home-grown material was encouraged by the Ministry of Supply. Saw-millers and woodworkers previously accustomed to working imported timbers found that modifications to the technique previously employed were essential, and many requests for advice and assistance in overcoming difficulties encountered reached the Laboratory. In this connexion it is worth recording that the sales of the Handbook of Home-grown Timbers so increased that six re-issues were necessary to meet the demand for copies between the end of 1941 and 1945.

CORROSION OF METALS CONTAINED IN WOODEN CASES

The use of unseasoned or only partially seasoned timber of certain species for crates and boxes used for the transport of armaments and apparatus was attended in many examples by serious corrosion of the contents. The matter was investigated at the Laboratory and the deterioration was found to result from a moist, acid condition of the air in the containers. Corrosion was found to be severe when unseasoned or insufficiently seasoned timber of oak, sweet chestnut or western red cedar had been used in the construction of the containers and a report on the results of the investigation with recommendations for minimizing losses from this cause was given wide publicity. It was found that the action on steel progressed so quickly that corrosion sufficient to render tools and spare parts useless could occur in a few hours when the containers or fittings were made of green timber of the above-mentioned species.

SEASONING

Before the war, hardwood lumber from foreign sources was frequently kiln-dried or partially seasoned before shipment, oak and mahogany from the United States being instances of imported timbers so treated. The cessation of supplies of such timber led to an acute shortage and to meet the increasing demand for thoroughly seasoned stocks it was necessary to increase the number of efficient kilns in Britain as quickly as possible. The Laboratory was called upon, under a scheme arranged with Timber Control, to report on plans for building new kilns, to inspect them on completion, to advise on the modernization of old kilns and to train kiln operators in kiln operation and management. This considerable extension of its own work made a heavy call on the services of the personnel of the Seasoning Section for several years and entailed the absence of one or other of the officers from the Laboratory. Nearly 400 firms had been visited by the end of 1945. Courses for kiln operators, of one week's duration, were arranged at short intervals.

RIFLE FURNITURE

Walnut was formerly used almost exclusively for rifle furniture in Britain but it became so scarce that in the very early war period a change to some other timber was unavoidable. Beech was selected as the substitute and the Laboratory was requested to arrange for the inspection of various parcels of

imported and home-grown beech for the Royal Small Arms Factory. Experimental work on the kiln-drying of beech "blanks" was undertaken and a suitable drying schedule was evolved. At one period the Laboratory was asked to undertake the drying of blanks on a considerable scale and was able to handle approximately enough to keep one of the small-arms factories running. As new kilns came into operation contractors were able to undertake this work, but they, in turn, frequently applied for advice and information concerning suitable treatment.

WOOD BENDING

Bent timber in both solid and laminated form was used for various purposes during the war, particularly in connexion with aircraft construction. Knowledge gained from pre-war experiments in wood bending proved of considerable value and further work was pushed forward with all possible speed. A method of making laminated bends, using thin strips glued end-to-end with a suitable adhesive, enabled small offcuts, which might otherwise have been wasted, to be used for the production of door frames and other parts of aeroplanes at a far greater speed than had hitherto been possible. The method was demonstrated to various contractors who by its adoption were able very materially to increase production.

TIMBER FOR AIRCRAFT

In the early part of the period under review an investigation of defects in veneers and their effect on the shear strength of plywood for technical uses manufactured from them was undertaken at the Laboratory. A new type of test was devised and panels made from veneers containing defects such as knots, wild grain, splits and decay were tested. The number of tests exceeded a thousand and the evidence obtained showed conclusively that defects such as those mentioned had far less effect on the strength of the manufactured plywood than had been supposed when the specification covering the veneers was drawn up. It was therefore possible to provide a new, less stringent specification which reduced the number of rejected veneers very considerably at a time when there was increasing difficulty in obtaining peeler logs.

At one period there was a prospective shortage of Sitka spruce for aeroplane construction and the Laboratory was called upon at short notice to undertake tests on possible alternative species including noble fir, hemlock, Douglas fir and Kara Sea redwood. In order to secure reliable information a long series of tests was necessary on each species, the total number running to many thousands.

PEELING TESTS

In an attempt to find satisfactory substitutes for Canadian birch for veneer for the manufacture of plywood for aeroplane construction, logs of home-grown and Empire species were peeled and, except in a few instances, plywood was subsequently made and tested. In the course of this investigation the suitability of beech for technical-grade plywood was demonstrated and, as is now widely known, large quantities of home-grown beech were subsequently used for plywood in aeronautical construction. Approximately fifty species were tested but very few were in any way comparable to Canadian birch for the purpose in view. The results of the tests proved valuable at a later stage when it was proposed to establish a plywood industry in West Africa and information was required in connexion with the scheme.

LAMINATED WOOD

Some exploratory work was carried out on the machining of laminated wood bonded with synthetic resins. This class of material tends to be refractory in manufacturing operations such as sawing, planing and boring, and investigations were undertaken with the object of finding satisfactory techniques and of devising suitable types of cutting tools. As a result the difficulties were largely overcome. The matter was the subject of numerous enquiries from both manufacturers and users of the material.

ADHESIVES

The testing of adhesives used in the manufacture of plywood and in the construction of aircraft was undertaken for the Ministry of Aircraft Production. The work included investigations into the technique of making satisfactory joints with different glues, strength tests of joints, the effect of moisture and temperature on the glue-line strength, causes of failures, reaction to prolonged exposure of plywood bonded with different glues and the effect of micro-organisms on adhesives in plywood of different types. The total number of sample joints tested exceeded a hundred thousand.

A chemical investigation of the factors immediately responsible for deterioration in the bonding properties of urea/formaldehyde glues in plywood made it possible to define the critical factors governing the durability of such adhesives and to indicate certain precautions which retard the succession of changes responsible for the loss of bonding strength.

In connexion with the work on adhesives, liaison with the manufacturers was maintained and this was strengthened, in 1945, by the formation of an Adhesive Makers' Panel at the meetings of which matters of mutual interest are fully discussed. In this way the general research problems of the industry are embodied in the Laboratory's programme.

FIRE RESISTANCE AND EXTINCTION

A standard method of testing fire-retardant paints against incendiary bombs was developed and became the basis of a British Standard A.R.P. specification. Many proprietary paints were tested in accordance with this specification. Tests were also carried out on behalf of the Ministry of Aircraft Production for the purpose of determining the efficacy of incendiary bombs.

A considerable amount of work was done in order to assess the value of chemicals in aqueous solution for extinguishing fires. In this connexion a " standard fire " was devised by using timber cut to definite dimensions built on a frame. Special apparatus was constructed to distribute the solution uniformly in each test so that direct comparisons could be made. The results showed that a number of chemicals, when added to water, increased its fire extinguishing effect considerably, even in relatively dilute solution. The more effective chemicals are ammonium phosphate, ammonium borate, ammonium chloride, ammonium sulphate, zinc chloride, calcium chloride and boric acid.

A more detailed study was made of two of these, namely ammonium phosphate and calcium chloride, as from an economic point of view these appeared to be the most suitable for practical application. The tests had for their object a quantitative assessment of their effectiveness.

The effectiveness of a chemical solution can be compared with that of water either by comparing the times required to extinguish a standard fire when applied at the same rate, or by comparing the rates of application necessary to extinguish the fire in the same time. In both comparisons the quantitative superiority of the solution varies with the rate of application, but

whereas in the first the superiority at low rates of application may approach infinity (i.e. when the fire is not quite extinguished by water), in the second the superiority tends to approach a constant maximum at low rates of delivery. The constant figure represents the maximum potential fire-extinguishing superiority of a solution and is a convenient figure for comparing the effectiveness of different solutions. It will be realized, of course, that only in relatively few fires will a solution be applied at such a rate that the maximum potential superiority is called into use, and in many the actual superiority will be less, depending on the rate of application of the solution relative to the size of the fire. Nevertheless, fires which cannot be controlled by the water available are the critical ones and it is in such conditions that the maximum superiority of a solution is involved.

PHYSICS

The work of the Physics Section of the Laboratory during the war period included research upon the elastic properties of wood and plywood, vibration, swelling stresses, and the flow of gases through wood. At all times during the period the section was called upon to discuss and to advise upon the physical aspects of the problems being dealt with by other sections of the Laboratory.

UTILIZATION OF WOOD WASTE

The problem of putting the considerable war-time accumulations of wood waste to good use led to more intensive investigations into its value as a fuel. A furnace with a hopper feed capable of burning sawdust or other finely-divided material was designed and later used for heating an experimental drying kiln heated by flue gases. Sawdust having a high moisture content may be employed to provide a satisfactorily uniform heat output and the furnace has the added advantage of low heat losses and of needing little attention during operation apart from periodic refuelling. Numerous enquiries concerning it were received from home and overseas after the publication of details.

SURVEY OF DAMAGE BY INSECTS IN NATIONAL STOCKS OF HARDWOODS

At the request of the Ministry of Supply, Timber Control Department, a survey of national stocks of hardwoods was undertaken to determine the extent of infestation by *Lyctus* powder-post beetles. Following recommendations based on the results of the survey, instructions were issued by the Timber Control Department that all instances of damage were to be reported.

Later, the question of preventing damage by *Lyctus* in utility furniture was taken up with the Board of Trade and it was arranged for their timber inspectors to visit the Laboratory for instruction.

Experiments carried out in 1942 indicated that green oak sapwood dipped in a 5 per cent solution of borax at 180°F. for one minute was rendered immune from attack by these pests. Further experiments confirmed the effectiveness of the treatment.

Cases of infestation in boxes containing imported foodstuffs were investigated on behalf of the Director of Infestation Control, Ministry of Food.

DRY ROT IN BUILDINGS

The Laboratory was approached for assistance in connexion with dry rot outbreaks in buildings damaged in air-raids. The dry rot was generally worst in buildings in which large quantities of water had been used to extinguish

fires. Officers of the War Damage Commission made use of the services of the Laboratory in elucidating many outbreaks where dry rot was attributed to war damage.

Other work on dry rot was connected with historic buildings, inspections being made on behalf of the Ancient Monuments Branch of the Ministry of Works.

The Ministry of Home Security sought assistance in connexion with the development of dry rot in basement air-raid shelters.

ADVISORY WORK

In all sections of the Laboratory there was a very great increase in the advisory work during the war period, and with a reduced staff this occupied a considerable portion of the time of officers qualified to undertake such work. The cessation of imports of well-known timbers necessitated the employment of other less-known species and where these were to be used for exacting purposes, as in the making of apparatus, in ship- and boat-building and in aircraft construction a sound knowledge of their technical properties was called for in the interests of safety and economy. Many enquiries were received from government contractors who had been allotted unfamiliar timbers by the Timber Control Department, and many for substitutes for such special timbers as teak and lignum vitae which, from the outbreak of war, were reserved for the Admiralty. Hickory and ash, much in demand for handles for naval and army stores, were very scarce and information with regard to possible substitutes was much in request. Other timbers important in war industries were box and dogwood, both of which were difficult to obtain in adequate quantities. It was not possible to find timbers capable of being substituted for all the purposes for which these special-purpose woods had been employed, but careful consideration of the peculiar properties called for in any particular use enabled suitable substitutes to be suggested for most. Other enquiries were directly traceable to the introduction of the new synthetic-resin adhesives. These were concerned not merely with the adhesives themselves and their proper application, but also with troubles in working plywood and other forms of composite wood in which they were incorporated.

PART II. WORK AFTER THE END OF HOSTILITIES

With the end of hostilities in 1945, attention was turned to putting the Laboratory as quickly as possible on to the footing necessary for meeting peace-time problems. A review which had been made in 1943 of post-war activities of the Laboratory had indicated the main lines of organisation required. Prominence had been given to the importance of making plans to put the Laboratory in a good position to meet the increasing requests by industry for advice and, generally, of making the results more effectively known. In addition there was the need for expanding the resources of the Laboratory both in men and material particularly in directions where great changes anticipated in the use of wood were likely to raise a fresh crop of problems which the Laboratory should anticipate and solve. Some of this reorganization was in fact already completed, or in train, in 1945 partly because of war needs.

It had been clear, for instance, that the small-scale plant for plywood research would no longer be adequate for post-war requirements, and plans were worked out for what would in effect be a complete plywood manufacturing unit so equipped as to permit of the greatest flexibility in working. Thus

it would be possible to carry out investigations upon detail or upon the full process of manufacture on the commercial scale. The plans were approved before the war ended, and building was begun in 1945. At the same time it was realized that the keeping qualities (including the ' pot life ' of the adhesive as prepared for use) and the technique of assembly of adhesives in the tropics would be a subject of importance to British manufacturers, it was decided to adapt the " Dry Rot " house (previously used for large-scale infestation with wood-destroying fungi and insects) as a tropical testing laboratory where adhesives and complete assemblies could be subjected to storage, or where actual assembly could be carried out under predetermined tropical conditions. Another project involving the adaptation of existing accommodation was the provision of a temporary ' structures ' laboratory for the testing and improvement of timber housing components and assemblies—a matter of importance in helping to combat the national shortage of timber for houses.

When it was clear that the war was moving to a favourable close, it was possible to survey our relations with other bodies and to take action with a view to improving liaison with them under peace-time conditions. For example, our relations with the Timber Development Association were clarified and extended. At the conclusion of the conversations the Association made the generous offer of a yearly donation of £1,000 as a mark of appreciation of the Laboratory's co-operation. This offer was accepted with thanks as an earnest of our more extensive future co-operation.

But apart from instances such as these, preoccupation with the winding-up of war-time work, and the general staff position limited the extent to which, by the end of 1945, it had been possible to restore the Laboratory to a peace-time footing. The following paragraphs, however, describe briefly the work recently completed and the position reached by the end of the year in the various research sections of the Laboratory.

WOOD STRUCTURE

The great change, brought about by the enormous consumption of timber in the war, in the relation of supply to demand, led to a renewal of interest in timber from new sources and particularly in the secondary species of the colonial forests, more especially those which might be suitable for the manufacture of furniture and plywood and other composites containing wood as a major constituent. A limited amount of work was done in 1945 on species not formerly utilized in Britain, to assess their suitability for such definite purposes as constructional work, furniture, shuttles, plywood, etc. With the prospect of improving transport facilities requests for tests on a further number of Empire timbers had already been submitted, and were being dealt with as rapidly as circumstances permitted.

Preoccupation with advisory work and the shortage of experienced staff precluded the resumption of regular research and have also prevented any substantial progress in the revision of out-of-print publications, for some of which there has been a considerable demand.

PHYSICS

The work on wood-water relations had been continued and a report published on swelling stresses in gels. Measurements of the rate of flow of non-absorbing gases through wood had been in progress in continuation of the earlier work. Investigations of the frequency of vibration of wood and plywood plates in relation to the elastic constants have been carried a stage further. Work on the measurements of strains in plywood panels by means of electrical resistance strain gauges was completed. A further qualitative

study of stresses in the glue layers of plywood had been made, which served to show the difficulties in the way of obtaining an exact theoretical treatment.

CHEMISTRY

A chemical investigation of the factors immediately responsible for deterioration in the bonding properties of urea/formaldehyde glues in plywood was carried to the point at which it was possible to define the critical factor governing durability in these adhesives and to indicate precautions which retard the succession of changes responsible for the loss of bonding strength.

The nature of a hard, white deposit met with in commercial samples of the timber of mandioqueira, *Qualea* species (probably *Qualea albiflora*) from Brazil, was investigated. The substance was found by analysis to consist of a mixture of normal and basic aluminium succinates. This is interesting as being the second recorded instance only of the occurrence of aluminium succinate deposits in wood in fifty years and a short account of the work was therefore prepared for publication.

An interesting instance of simultaneous corrosion of metals and decomposition of wood in boats was investigated. The boats were constructed with a double skin of mahogany planking, fastened with brass screws and copper nails. Water had percolated between the outer and inner skins and stray electric currents arising from leakages from electrical equipment in the boats had caused electrolytic action attended by corrosion of the metal and deterioration of the wood in its vicinity.

ENTOMOLOGY

Biological investigations on the powder-post beetle, *Lyctus brunneus* and the common furniture beetle, *Anobium punctatum*, which had been impossible during the war years, were restarted. A series of experiments to determine the efficacy of certain chemical treatments for the prevention of infestation of timber by *Lyctus brunneus*, started during the war period, were carried further, and certain treatments shown to be ineffective. Preliminary tests with D.D.T. and Gammexane indicated that some formulations of these insecticides offer distinct possibilities and the work has been extended. Exploratory tests of their effect on the death-watch beetle, *Xestobium rufovillosum* were also begun.

Following numerous enquiries from government departments and industrial sources concerning termites in relation to the export trade to tropical countries, a small colony of the dry-wood termite, *Cryptotermes brevis*, was obtained from the Imperial College of Tropical Agriculture, Trinidad, to provide material for research.

MYCOLOGY

Routine tests of a number of proprietary wood preservatives were made on behalf of the Ministry of Supply and at the request of manufacturers.

An investigation of the resistance to decay of wood impregnated with methylol urea showed that the treatment, though definitely increasing resistance to decay, does not render the wood immune as has been claimed.

A comprehensive series of tests on the relative resistance to decay of rock elm and American white elm showed that the latter is inferior in durability even when of the same density as the former.

Routine tests of the resistance of three West African timbers and of numerous composite building boards to the action of the more virulent rot-producing fungi were completed. On behalf of the Ministry of Supply tests of the resist-

ance of a wide range of materials to mould attack were carried out. Routine testing of the resistance to micro-biological attack of adhesives used in plywood continued.

The influence of incipient decay produced by a white rot and a brown rot on the tensile strength of beech was investigated, and the effects of the two fungal types were compared.

A text book on timber decay and its prevention was prepared for publication.

SEASONING

The experimental kiln at Lyndhurst, heated by gases from a sawdust-burning furnace, after being fitted with an automatic temperature-control system, has proved satisfactory for the drying of softwoods. The water-drip system of humidification used, however, did not permit of the production of the high humidities necessary for effective conditioning and relief of case-hardening. Details of this kiln were published in 'Wood', September 1944.

Tests were carried out to investigate the effect of treatment with urea on drying rate and seasoning degrade. In no test was the drying time shorter nor the degrade less in treated samples than in untreated controls. Following numerous enquiries for information about the rate at which timber in damp condition absorbs moisture, experiments were carried out on seven species. In the course of this investigation it was found that the rate at which moisture was given up on redrying was appreciably greater than that at which it had been absorbed.

WOOD BENDING

An investigation to determine the causes of twisting in laminated bends was completed. Causes of glue line fracture in bends of laminated construction were determined. An investigation of the influence of various adhesives on the final shape of laminated bends was made.

Tests of the relative behaviour in bending of (a) sliced and (b) sawn laminae were completed. It was shown that when using sliced laminae the "loose" face should be on the inner or compression side of the bend.

Work on the investigation of the bending properties of plywood was continued.

Work on the bending of solid wood has largely been related to furniture manufacture and the boat-building industry.

COMPOSITE WOOD

Long-term test work on the durability of adhesives for wood under standardized conditions of exposure was extended. The results of this work will ultimately determine which adhesives can be relied upon to give entirely satisfactory results when employed in plywood for exterior use.

The possibility and desirability of accelerating the setting of synthetic resin glues by the use of infra-red lamps for heating were investigated on behalf of the Ministry of Aircraft Production. The suitability of the method for application to specific processes was demonstrated.

Exploratory investigations of radio-frequency heating as applied to the setting of glues were made, with a view to planning systematic research in the most profitable directions.

The moisture relations of various composite wood products, including plywood and laminated improved wood, were studied and an investigation of

the influence of various types of glue on the permeability of plywood to water was started.

TIMBER MECHANICS

The failure of a number of aircraft wings was suspected to be due to overstressing the tension boom of the spar in compression as a result of inertia effects in landing. A method was developed for the investigation of the influence of overstressing in compression on tensile strength.

Packaging investigations extending over a wide field were undertaken for the Ministry of Supply and service departments. Waterproof case-liners and paper packing materials of various types were included in the investigations. Tropical cyclic tests were made on the packages containing many kinds of stores. Tests on fibreboard for the manufacture of containers were undertaken on behalf of the Dairy Division of the Department of Agriculture, New Zealand. The bursting strength and resistance to the passage of moisture vapour of paper were evaluated and new patterns of wood and plywood boxes were tested.

Standard abrasion tests on a number of floor-finishing materials were undertaken for the Ministry of Works, and on resin-treated plywood flooring panels for a private firm.

The report on the investigations into the strength of home-grown pitwood, undertaken at the request of the Forestry Commission, was completed.

Other miscellaneous investigations included (1) tests to determine the influence of a fire-proofing treatment on the impact strength of white seraya, (2) exploratory tests on three different timbers treated with dimethylol urea, and (3) investigation of the influence of exposure to moisture on the strength of a fibreboard (for the Ministry of Aircraft Production).

WOOD-CUTTING RESEARCH

An investigation to determine the relation of tooth-pitch and rate of feeding to power consumption and sawn finish in ripsawing with circular saws was undertaken.

A preliminary study of the cutting properties of perspex was made, in which the importance of cutting speed, skew angle and the sharpness of the cutting edge was demonstrated.

Photomicrographic studies were made of the wood of four species which were rotary-cut at slow speed. Useful information on various types of failure of the wood under the cutting edge in differing conditions was recorded. Path diagrams for swage-set and spring-set teeth of circular saws, velocity and acceleration diagrams for frame saws, and other geometrical developments were completed.

Conversion trials were carried out on stems taken out in thinning operations for the Forestry Commission. Seven different species were converted and it was shown that trees over pitwood size, if converted by suitable methods, would yield a relatively high percentage of material of a quality suitable for various industrial purposes.

The design for an experimental planing and moulding machine for advanced research work was completed and the necessary specification prepared.

The preparation of a handbook on wood-cutting was completed early in the year.

F. Y. HENDERSON,
Director

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1946

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board, beg leave to submit our Report for the year 1946. The period under review has been one of transition from war to peace conditions and has been attended by difficulties inevitably associated with bringing to an end a long series of *ad hoc* investigations and the resumption of an organized, long-term programme of research. Several factors have, moreover, operated to increase these difficulties. For instance, there has been an unprecedented influx of new or little-known timbers from Empire and foreign sources, and many importers and users have sought information concerning their physical properties, seasoning and working qualities, and possible suitability for specific industrial purposes. It was imperative to meet, so far as was reasonably possible, the demands for this type of information in order to retain the confidence of the industries which it is the responsibility of the Laboratory to serve, and perusal of the Director's report discloses the extent of the time spent upon this service. This work has made heavy inroads into the time of senior officers who, in more normal circumstances, would have been fully occupied with research work. A second factor militating against the rapid transition from the activities of war to those of peace has been the difficulty of obtaining apparatus required for new research and for the replacement of obsolescent or outworn plant, a difficulty which only time can overcome. A further cause of the slow recovery from the abnormal war-time conditions has been the dearth of suitable recruits for replacing the wastage of staff in the period since 1939 and for expanding the staff of the various sections to meet changed conditions. This shortage, which has been one of our chief preoccupations, cannot fail, if it persists, to have the most grave repercussions upon both the short-term and the long-term activities of the Laboratory. Occupying as it does a unique position in regard to a highly diverse and largely 'traditional' industry which is daily becoming more technically minded, it is clear that much of the time of its present staff must be spent upon advisory work and the supporting *ad hoc* investigations. At the same time we view with concern the restriction which this and the aggravating factor of shortage of staff place upon the resumption of longer-term work of wider and less immediate application. Indeed the future capacity to meet the needs of *ad hoc* problems and enquiries is entirely dependent upon progress in fundamental knowledge and we therefore trust that everything possible will be done to expedite the acquisition and training of recruits to the Laboratory staff.

All timber-using industries have been adversely affected by the timber shortage, the building and furniture industries particularly so. The building of boats has virtually been brought to a standstill. In the textile industry suitable woods for shuttles and picker arms have been in very short supply. In consequence, trade associations have sought assistance in their efforts to find new species possessing the special properties necessary in timbers for these articles, and indeed the search for substitutes is at present a very important aspect of the work.

RESEARCH

In the field of research we have to report a limited resumption of fundamental work. Testing of the hypotheses of the behaviour of gels under stress has been continued. From these tests a possible explanation of the cause of ' collapse ' in timber during seasoning has been suggested. Further work on the elastic behaviour of wood and plywood plates has been done, and an investigation of creep under sustained load and of damping of natural vibrations has been started. Experiments to elucidate the factors governing the permeability of timber to air and water-vapour have been in progress. Work has been resumed on the lesser known wood polysaccharides of oak and of larch, and the abnormal ' tension ' wood of beech has been investigated by a British Council Scholar from China.

The acute shortage of timber in Britain has created fresh interest, both in this country and in the colonies, in the possibility of exploiting hitherto neglected secondary timbers growing within the Empire, and a programme of tests on some of these has already been embarked upon. It is expected that the work involved will extend over a number of years, as in the past only a small proportion of the species indigenous to the forests of the colonies has been utilized. This work may ultimately be of very considerable indirect advantage to forestry departments in that it will check the practice of extracting only a few of the better known and more valuable species and will thereby contribute to the efficient management of the forests.

Experiments on the setting of glue by radio-frequency heating have been carried out, as well as investigations of the possibilities of seasoning wood by this method. Other novel methods of extracting surplus water from wood have been studied.

The possibility of modifying the properties of a cheaper or more readily available timber to impart to it special properties essential to its use for specific purposes has been investigated in an attempt to overcome the acute shortage of certain species, some particular inherent qualities of which have led to their almost universal application in industry for such purposes.

The mycological work on the longevity of fungi in dry wood is continuing.

CONTACTS WITH SCIENTIFIC WORKERS OVERSEAS AND IN BRITAIN

We note with satisfaction the resumption of mutually advantageous exchange arrangements with scientific institutions, forestry departments and individuals in overseas Empire and foreign countries. Scientists and students in countries occupied by the enemy were virtually cut off from contact with the outside world, and it is a matter of gratification that the Laboratory has been able to give assistance to them in the resumption of their work and to take up again the relations which existed before the war.

The maintenance of cordial relations with universities, technical institutions, architectural associations, trade associations and the technical and trade press is also noted with satisfaction. Friendly intercourse between scientific workers investigating similar problems from different angles must be mutually advantageous, and close contact with professional and trade associations serves the double purpose of transmitting to their members the results of research and of informing the Laboratory of new problems arising in industry.

The Director reported that the four officers in charge of the Chemistry, Woodworking, Composite Wood and Wood Preservation sections respectively, had attended the Congrès International pour l'Exploitation et l'Utilisation Rationelles du Bois, in Paris, and that the papers read by them had been well received.

The Board also took note of a report on the sawmilling and woodworking industries in West and East Africa, which was based on observations made by Mr. P. Harris during a tour undertaken at the request of the Colonial Office.

We view with satisfaction the steady flow of publications of a scientific and technical nature to meet the demand which shows a widening appreciation of the value of the work of the Laboratory, as evidenced by the relatively large demands for its books and leaflets and for reprints of reports and articles in scientific and technical journals. The ready acceptance by other government departments, including the Board of Trade, the Directorate of Furniture Production and the Ministry of Works, of the Laboratory as a reliable source of information on all matters pertaining to the utilization of timber, and particularly with reference to the rebuilding of the House of Commons and the repair of Westminster Hall, is also gratifying.

E. J. SALISBURY,
Chairman

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1946

INTRODUCTION

The Laboratory, when hostilities ceased, was engaged in a number of investigations related directly or indirectly to the prosecution of the war. Of these some promised to yield results which would be of value to industry at a later date and it was inexpedient, in consequence, to bring them to an abrupt end in an unfinished state. The general resumption of longer-term research work, therefore, has suffered some delay. In the years between 1939 and 1946 the scientific and technical staff had been seriously reduced by deaths and by the transfer of officers to war work in other government departments. The transition from the *ad hoc* investigations, which characterized the war years, to the organized and carefully planned programme of research, which had been under consideration in the previous two years, was hampered by the difficulties of recruiting staff and of securing new apparatus and machines to replace those which had become worn-out or obsolescent. The Laboratory was, moreover, at a temporary disadvantage in comparison with the industries it serves, for in them, and particularly in the furniture industry, firms had already reverted or were reverting by the end of 1944 to the manufacture, on a large scale, of goods for post-war consumption. The difficulty of obtaining timber in pre-war quantity, quality and sizes had led to the use of substitutes and to new designs and necessitated the adoption of new methods of manufacture and the modification of older ones. All these developments brought many enquiries and problems to the Laboratory. The rapid advance in the knowledge of synthetic resins in the war period, followed by their widespread use in industry, particularly in the form of adhesives and surface coatings, also introduced new problems connected with subjects such as methods of application, 'crazing' through the use of unsuitable hardeners, and troubles in working wood and plywood containing synthetic resin adhesives. The difficulty of completing the reorganization and resuming a full scale programme of research was further aggravated by an unprecedented influx of new timbers from Central and South America, and from sources within the Empire. There was little or no reliable information available about many of these, and the Laboratory was inundated with questions as to their properties and suitability for specific purposes or for use as substitutes for teak or other special-purpose timbers which were generally unobtainable. Small-scale tests on as many as possible were undertaken, largely at the request of the Timber Control, but with the facilities available it was impossible to examine more than a small minority of them. Much time was occupied in consulting literature and in replying to enquiries, and it has been, in consequence, very difficult to make headway with actual research included in the long-term programme. These examples will serve to indicate the general impact of peace-time conditions upon the programme of the Laboratory as a whole. It is clear from the steeply rising influx of requests for information and advice that general resumption of research must await the recruitment and training of staff, and that for the near future priority must be given to short-term and *ad hoc* investigations. Surveyed with this in mind, the past year has in some measure been an unsatisfactory one, yet much assistance has been given to industry during the period and there is compensation in the ample evidence of appreciation of the help given, and of the increasing reliance of trade

directorates upon the information supplied by the Laboratory and upon its publications.

GENERAL

BUILDINGS AND EQUIPMENT

During the year definite though slow progress has been made in the provision of new buildings and equipment. The new composite-wood building was completed, and the new machinery has begun to come in. The tropical testing house, now structurally complete, awaits its conditioning plant, and a new concrete hut for timber mechanics section has been erected. Gradual acquisition of temporary huts from the Ministry of Works has begun to relieve the congestion in several sections and has provided sorely needed room for lectures and, when time permits, for a museum and an exhibition for visitors.

TOURS

A tour of inspection of the sawmilling and woodworking industries in West and East Africa was made by the Officer in Charge of the Woodworking Section on behalf of the Colonial Office. Forestry department headquarters, forest stations and reserves, workshops of the Public Works departments, government railways, commercial firms and some forty sawmills were visited in Sierra Leone, Nigeria, Kenya and Uganda. The tour occupied twelve weeks and a full report on it has been issued.

FURNITURE WORKING PARTY

The Director continued to serve as an independent member of the Party until the completion of its work and the publication of its report in August, 1946.

RESUMPTION OF EXCHANGE ARRANGEMENTS

Since it became possible to resume exchange arrangements, collections of timber specimens have been received from China, Brazil and French Equatorial Africa. These together constitute a very useful addition to the standard collection of wood specimens.

Demands for wood specimens for teaching and study have been extremely numerous, largely as a result of increased interest in wood technology and the inauguration, in consequence, of courses in the subject at a number of technical institutions in London and the provinces. The number of specimens distributed to instructors, private students, and timber firms in the course of the year exceeded five thousand. It is evident that timber users are more appreciative of the value of technical knowledge in industry than ever before.

COURSES OF INSTRUCTION

Visits of students from the British universities at which forestry is taught have now become annual events. Students from Oxford attended a ten-day course in January in utilization. The students were keenly interested and, after the course, a request for a similar one in ensuing years was received from Oxford. Individual courses for forest officers and students wishing to specialize in some particular branch of wood technology were also arranged and a special course in wood structure and woodworking was held towards the end of the year for a number of students from industry. Courses in kiln-seasoning have been held at intervals of three or four weeks throughout the period. Instruction has also been given to students from the universities of Cambridge, Edinburgh, Aberdeen and Bangor. The number of applications

for general courses shows no signs of decreasing but in existing circumstances it has been quite impossible to comply with all the requests received during the year.

LECTURES

Apart from the lectures delivered to students at the Laboratory a number of others were given by various officers in Leicester, Sheffield and other centres.

PROGRAMME OF RESEARCH

WOOD STRUCTURE

Identification of Timber Specimens

Mention has already been made of the increasing demand upon the services of the Laboratory for advisory work. The burden of this has fallen heavily upon the Wood Structure Section, which lost two of its three officers to war service in other departments. As a result, research in the field has been almost entirely confined to *ad hoc* investigations. The issue by the Board of Trade, Timber Control Department, of licences for the import of timbers not included in their own procurement list has led to many enquiries concerning species new to British markets, and these have included timbers from Ecuador, Peru, Venezuela, Dutch Guiana, the West Indies, and Portuguese East and West Africa. More than 600 specimens of wood, concerning which enquiries were received, have been identified during the year, and technical notes on the more important species have been prepared for distribution to the trade.

Empire Timbers

The need to utilize, both in the countries of origin and in Britain, more of the secondary timbers growing in the forests of the various colonies is now patent. The heavy exploitation of some of the traditional primary species and the decreasing availablity of timbers hitherto bought from hard-currency areas give point to this need, and an extensive programme of research is envisaged in consequence. During the year several applications for tests of Empire timbers were submitted, and preliminary arrangements for the supply of test material of species from Nigeria and British Guiana have been made. A parcel of mubura—*Parinari* species—from Uganda has already arrived and the work of assessing its physical and technical properties to determine its most suitable uses is in hand. Tests on celtis from Nigeria were also completed during the year.

The search for a substitute for American persimmon and cornel for shuttles has continued under rather difficult circumstances. Encouraging reports on two promising species of *Diospyros* in Nigeria and the Gold Coast proved to be based on faulty information as to possible supplies, while the first of two trial consignments from Kenya, supposed to be *Apodytes dimidiata*, proved to be another timber shipped in error, a type of difficulty which sometimes occurs despite all precautions. Consignments of two other possible timbers, *Elaeodendron buchananii* and *Pygeum africanum*, have since been received from Kenya.

Balsa Wood Grown in Ceylon

Samples of balsa grown in Ceylon were received for a report on their quality and for advice on the probable future demand for this timber. From the limited quantity examined it would appear that balsa of a quality suitable

for export could be grown in Ceylon, provided that care in the selection of suitable sites for its cultivation was exercised.

PHYSICS

Wood-water Relationships

(a) *Sorption and Swelling*

The experimental work on the sorption and swelling of wood under restraint, which was undertaken to test certain theoretical equations[1], has been continued.

The conditioning of clamped samples even in the absence of air is a slow process, and so far only two runs have been completed, but the experience gained has been used to improve the technique in the present series. The first run, in which clamped samples were moved from an equilibrium humidity of 32·8 per cent to one of 74·8 per cent, showed that the average volume swelling could be reduced from 4 per cent for free samples to 0·4 per cent in the clamps, while the average change in moisture content was reduced from 7·0 per cent to 5·8 per cent. Since the elastic constants are derived from these reductions of sorption and swelling, the results show that the moisture content change requires to be measured to a greater accuracy than does the swelling.

Two sets of readings gave 2946×10^6 and 2968×10^6 dynes per sq. cm. for the bulk modulus of spruce at an average humidity of 53·8 per cent. These are concordant values and are in good agreement with former determinations. The apparatus was not well adapted for measurements of the Young's modulus owing to some restrictions to the free lateral swelling of the samples, but the values obtained for the two sets were 4981×10^6 and 6671×10^6 dynes per sq. cm. as against 4760×10^6 and 4160×10^6 obtained by mechanical testing.

The same experiments could be used for calculating some of the elastic constants of the wood substance of the spruce cell wall. Four sets of values could be obtained from each of two samples and the results are given in detail in Table I to show the degree of reproducibility of the results.

TABLE I

Elastic Constants of the Wood Substance of Spruce

Sample No.	Bulk Modulus $\times 10^{-6}$	Transverse Constants		
		Rigidity $\times 10^{-6}$	Young's Modulus $\times 10^{-6}$	Poisson's Ratio
2	86500	2130	8320	0·952
	86650	2530	9830	·943
	84750	2720	10500	·939
	85250	2105	8210	·951
5	86100	1725	6760	0·960
	87900	1705	6750	·972
	84400	1990	7780	·955
	85700	2430	9460	·945

[1] BARKAS, W. W. Swelling Stresses in Gels. *For. Prod. Res. Sp. Rep.* No. 6. (H.M.S.O., 45, 1s. 2d. post free.)

The transverse Young's modulus may be compared with an approximate estimate of the longitudinal Young's modulus of the wood substance, namely, 302,000 $\times$ 10^6 dynes per sq. cm. obtained by calculation from the constants of the gross wood.

The results of the second set of experiments have not yet been fully analysed. In the first experiments, previously reported, the restraint was imposed in both the radial and tangential directions and these were found to yield satisfactory values for the bulk modulus but were unsatisfactory for the calculation of the Young's modulus. In the second set, the samples were subjected to a single restraint, either radial or tangential, and the values for the Young's modulus are much better though the bulk modulus values are correspondingly less satisfactory owing to the less complete restraint on the volume swelling.

A report by Gurney[1] has appeared which develops the theory of swelling on a purely mathematical basis, including effects due to temperature changes. This is a development of the work done here on swelling stresses. A second fundamental and purely mathematical treatment has been made by F. W. Warburton of the Wool Research Association[2]. Both these papers introduce more complete generalizations and deal with one or two points on which our original treatment could be improved.

An apparatus has been constructed for routine determinations of sorption isothermals of wood *in vacuo*. It is based on the quartz spring method of McBain and means are provided for waterlogging the samples *in situ*.

(b) *Collapse of Capillaries*

A point of possible importance to the problem of collapse in seasoning wood has emerged from a recent discussion with Dr. W. H. Banks of Printing and Allied Trades Research Association. The cells of wood resemble fine hollow tubes which, in the green state, are partially filled with water. As the tube dries out under a falling vapour pressure, the water is brought into a state of hydrostatic tension, which tends to pull in the walls of the tube. This reduction in radius of the tube means that a lower vapour pressure is required to evaporate the water and that the tension in the water will now be further increased. It can be shown mathematically that, for a tube made of wood substance, the tension will increase more rapidly than will the resistance of the tube to further compression and that there is a limiting vapour pressure below which it is impossible to remove the water from the smaller capillaries without complete collapse of the cell cavities. For materials of low rigidity, such as wet wood at high temperatures, this vapour pressure may correspond to relative humidities as high as 90 per cent or 95 per cent so that anomalous shrinkage will occur in the early stages of drying.

A note on this subject has been published[3].

(c) *Permeability*

Experiments on the permeability of wood discs continue and data are being collected but no analysis has been attempted in the period under review.

[1] Gurney, C. Thermodynamic Relations for two Phases, Containing two Components, in Equilibrium under Generalised Stress. *Rep. Roy. Aircr. Est.* No. MAT. 13, 1946.

[2] Warburton, F. L. Some Thermodynamic Relations of Rigid Hygroscopic Gels. *Proc. phys. Soc.*, 1946, **58**, 585–597.

[3] Banks, W. H., and Barkas, W. W. Collapse of Capillaries in the Drying of Porous Gels. *Nature*, 1946, **158**, 341–342.

Elastic and Allied Properties of Wood and Plywood

Apparatus

In all the work hitherto carried out in the Section on vibration properties of wood and plywood the mains frequency has been used as the reference standard. During recent months, it has become evident that this standard can no longer be relied upon, and information obtained from the Central Electricity Board has shown that the mains frequency is, in fact, liable to fluctuate between about 46 and 52 cycles per second. Some time has therefore been spent in making the standardization of the vibration apparatus independent of the mains. In the first place, an alternating current bridge of the Wien type was assembled, which enabled the frequency to be determined in terms of capacities and resistances. This proved satisfactory up to a point, but it covered only a limited frequency range (about 500 to 5,000 cycles per second), and these limits could only be extended at the expense of a considerably more complicated assembly. After consultation with the Electricity Division, National Physical Laboratory, a Dye sonometer lent by them covering the frequency range 100 to 10,000 cycles per second has proved entirely satisfactory. It has been incorporated in the vibration apparatus and is now always used to standardize the frequency.

Plywood Plates—Frequency of Vibration

The experimental work on the frequency of vibration and central deflection under load of plywood plates cut at various angles to the grain has been completed. Results are now available for 48 18 × 18-inch plates with clamped and supported edges, and the same number of 18 × 12-inch plates, obtained by cutting down the 18 × 18-inch size. Measurements on the further reduced size of 12 × 12-inch have also been carried out. A full analysis of the results will not be made until the experimental work is completed, but certain provisional conclusions can be drawn from the results so far available. In the case of plates having the face grain parallel and perpendicular to the sides (0°-90° plates,) the conclusions of an earlier but less complete investigation into the frequencies are confirmed in that the observed frequency of vibration with edges clamped is about 20 per cent lower than the calculated frequency, while the observed frequency with edges supported is about 20 per cent higher than the calculated frequency. Exact theoretical expressions for the frequency of vibration of plates having the face grain inclined to the sides are not yet available, and the results for such plates have, therefore, been analysed on an empirical basis. Earlier experiments on 0°-90° plates suggested that the frequencies could be predicted empirically in terms of plate dimensions, and the present results show that this treatment can be extended to plates at other grain angles. One rather surprising result which emerges is the very small effect of grain angle on the frequency of vibration and central deflection of square plates. Although individual points show some scatter, the average results for plates with grain angles of $22\frac{1}{2}°$ and 45° do not differ significantly from those observed on 0° plates, but this generalization cannot be expected to hold for oblong plates.

Plywood Plates—Static deflection

Comparison of observed and calculated deflections under static load can only be made for 0°–90° plates with supported edges, since no theoretical solution has yet been derived in other cases. The comparison shows that the agreement is reasonable, but that the plates deflect somewhat less than theory predicts. Thus, just as in the case of frequency of vibration, the results indicate that the frame used to hold the plates in the supported-edge condition imposes some restraint additional to that assumed in deriving the theoretical solution.

An empirical method of predicting the deflections analogous to that used for the frequencies has been developed and applied to the remaining cases. The method gives fair results, but it is not possible to estimate the deflections with the same accuracy as the frequencies.

Damping Capacity and Creep of Wood

About 200 references have been collected dealing with the allied topics of damping capacity and creep. About half of these references relate to non-metallic materials, but in spite of the volume of work which has been done, it appears that there is no general theory available to account for the observed effects. Empirically it is found for wood and several other materials that the damping capacity is independent of frequency. However, the available data for wood in torsional vibration only cover frequencies up to a few cycles per second, and attempts are now being made to extend the frequency range to about 1,000 cycles per second. From the few preliminary measurements so far made it appears that considerable difficulties will have to be overcome before accurate measurements can be made ; in particular, special precautions may have to be taken in order to avoid energy transfer between the vibrating wood and the supporting system.

A few observations have been made of the creep and recovery of a Douglas fir 5-ply plate under sustained shear load, using an apparatus which is the same in principle as that developed at the United States Forest Products Laboratory to measure shear modulus. The results are useful as indicating the order of magnitude of the effects, but the work has thrown some doubt on the validity of the method of loading. It is hoped to carry out some experiments by the alternative method of torsional loading in the near future.

Gloss

Following a lecture given last year before the Paper Manufacturers Association on The Optical Analysis of Glossy Surfaces, there has been a revival of interest in the work done here on the subject. Recently Dr. V. G. W. Harrison of Printing and Allied Trades Research Association has published a paper[1] in which the analysis is used on a surface of magnesium oxide. He obtained an average cosine scattering coefficient equal to 0·81 of the flux emitted normally under normal illumination compared with our value of 0·83, but he refines the analysis to allow the coefficient to vary with angle of illumination. He concludes that the analysis is of limited value in connection with surfaces of such low gloss as magnesium oxide, a view with which the author of the method would concur. The analysis was originally intended to be used as a measure of the ' finish ' of machined wood surfaces, but was found to be inapplicable. In his recent book[2] Dr. Harrison has, however, adopted it tentatively for use in measurements on paper.

In a test on the subjective judgment of gloss on paper, co-operation was given by about a dozen volunteers from the Laboratory's staff.

Stresses in Paint Films

As a result of an enquiry by the National Gallery, an attempt was made on an analysis of the stresses set up in a paint film caused by swelling of the wood beneath. The investigation was an interesting one, but it was not found possible to make a successful analysis of the stresses.

[1] HARRISON, V. G. W. The Light-diffusing Properties of Magnesium Oxide. *Proc. phys. Soc.*, 1946, **58**, 408–419.

[2] HARRISON, V. G. W. The Definition and Measurement of Gloss. (Printing and Allied Trades Research Association, 1946.)

CHEMISTRY

Lesser Known Wood Polysaccharides

Wood Starch

In the early part of 1939 a method was developed for isolating starch in granular form from the parenchymatous cells of oak sapwood. The method has recently been improved and samples of starch from two species of oak have been prepared for constitutional study under the direction of Professor E. L. Hirst, F.R.S.

The ε-Galactan of Larch Wood

Samples of this polysaccharide have been prepared from home-grown larch wood for constitutional study under the direction of Professor Hirst. A paper embodying some of the results has been prepared for publication in the Journal of the Chemical Society.

Chemical Composition and Properties of Tension Wood of Beech

In beech, as in certain other trees, there occurs a type of timber—tension wood—which is associated with unusual conditions of growth, e.g. on the upper side of slanting trees, and which has abnormal shrinkage and mechanical properties.

In a study carried out at the Laboratory by Mr. K. Y. Chow, a British Council Scholar, it has been found that the tension wood of beech (*Fagus sylvatica*) is less highly lignified and has a higher cellulose content and lower pentosan content than normal wood of the same species. These results are in direct confirmation of the findings of the Australian Forest Products Laboratory for the tension wood of *Eucalyptus regnans*[1]. Indications were obtained that the cellulose chain molecules in the fibres of beech tension wood, as opposed to the cellulose chain molecules in normal beech fibres, are more highly orientated in the direction of the long axis of the fibres and of the tree itself. This finding was confirmed by X-ray investigations at Leeds University on material from the same source by Dr. R. D. Preston and Dr. V. Ranganathan. In the published account of his work, Chow[2] took the view that the abnormal longitudinal shrinkage exhibited by tension wood on drying below the fibre-saturation point is not, as hitherto supposed, associated directly with the angle of inclination of the cellulose fibrils in the wood cell walls. Chow found in the cell walls of tension wood ' markings ' which he took to be minute transverse cracks indicative of a stretched condition in the green wood ; he accordingly suggested that the closing, during the drying of tension wood, of innumerable cracks of this type and distribution accounts, in large measure, for the well known abnormal longitudinal shrinkage. This view was not supported by Preston and Ranganathan[3] who did not, however, on their part offer an explanation of the phenomenon.

Wood as a Causal Factor in the Corrosion of Metals

Enquiries received at the Laboratory have revealed certain circumstances in which the rain-water extract from western red cedar (*Thuja plicata*) roofing shingles can cause rapid acceleration of the corrosion of zinc and lead when

[1] DADSWELL, H. E. (Division of Forest Products, C.S.I.R. Australia. Private communication.)

[2] CHOW, K. Y. A Comparative Study of the Structure and Chemical Composition of Tension Wood and Normal Wood in Beech (*Fagus sylvatica* L.). *Forestry*, 1946, **20**, 62–77.

[3] PRESTON, R. D., and RANGANATHAN, V. The Fine Structure of the Fibres of Normal and Tension Wood of Beech as Revealed by X-rays. *Forestry*, 1947.

either of these metals is used in the contruction of eaves, gutters, valleys, etc., of shingled roofs. If the design of the roof is such that the rain-water shed from the cedar shingles has to pass over bare metal inclined at a very steep slope, rapid and progressive corrosion of the metal is liable to take place over these sloped areas. Similarly, dropping of rain-water from cedar shingles has been found, in certain circumstances, to cause extensive perforation of lead valleys in under 10 years.

The rain-water extract of western red cedar is usually acidic, and some samples may have a pH of as low as 3·00, owing to the presence of tannic acid and of dehydroperillic acid, which latter is specific to western red cedar. Experiments in the Laboratory have shown that the acid extract from this wood can, in some instances, dissolve the protective coating which normally develops on zinc and lead exposed to the weather and promote attack on the metal. This attack is, at first, relatively rapid and is accompanied by considerable evolution of gas. At the same time, however, the acids in the extract are progressively neutralized through interaction with metal to form salts such as tannates which are insoluble in water and in dilute solutions of the wood acids. When conditions are such that these insoluble salts can form a deposit on the metal, either the rate of corrosion of the latter is substantially reduced or the corrosion is arrested.

Where metal is inclined at a steep slope or where it is subject in any locality to the scouring action of rain-water dripping from shingles, the metallic salts of the wood acids tend to be washed away as soon as they are formed. Consequently, corrosion of metal in such localities is progressive while rain-water continues to extract acid of low enough pH from the shingles. There is evidence that the acidity of the rain-water extract from cedar-shingled roofs decreases in course of time but, in any particular instance, the rate of decrease in acidity will, of course, depend on several variables including those inherent in the wood itself, annual rainfall, etc. In view of the above findings it is advisable to protect susceptible areas of metallic components of new shingled roofs by a bituminous or other suitable paint.

Most of the common woods impart acidity to any water with which they are moistened. In a series of observations carried out at the Laboratory on various samples of some 60 wood species, only two were found to render water alkaline. These were quipo (*Cavanillesia platanifolia*), which gave values of pH of up to 10·26, and balsa (*Ochroma lagopus*), some samples of which may give a pH of up to 8·00. It has been shown[1] that the pH of water in contact with a metal may have a marked influence on the rate of corrosion of the latter. At ordinary room temperatures (up to 72°F.) corrosion is slow at pHs greater than 10. The rate of corrosion is somewhat greater when the pH lies between 10 and 4·3 but, when the pH falls below 4·3, corrosion of metal is rapid. So far, samples of 20 species of wood have been found (after moistening) to give a pH of 4·50 or less and they include oak, chestnut and *Eucalyptus* (five species), among hardwoods, and spruce, pine, larch, Douglas fir and western red cedar, among softwoods. These are the woods which are most commonly associated in industry with corrosion of metals embedded in or in contact with them under wet conditions, i.e. when the moisture content of the wood is of the order of 20 per cent or higher.

An account of several factors found to be involved in the utilization of wood in association with metals was presented at the Congrès International pour l'Exploitation et l'Utilisation Rationelles du Bois, which was held in

[1] SPELLER, F. N. Corrosion Causes and Prevention. McGraw-Hill Book Co., London, 1935, (p. 28 et seq.).

Paris in September, 1946. The paper has since been accepted for publication by the Ministry of Supply as a Scientific and Technical Memorandum[1].

MYCOLOGY

During the year 1946, it was possible to begin only a few new lines of research, owing to the continuing shortage of staff, and most of the available time was spent on advisory and testing work and in teaching students and demonstrating to visitors at the Laboratory. A new programme has been drawn up and it is hoped early in 1947 to undertake more experimental work.

Physiology of Wood-destroying Fungi

The experiments on the longevity of fungi in dry wood have been continued, cultures being taken at intervals from samples of wood kept in atmospheres of various relative humidities. It has already been established that some species can remain alive in wood that has been kept for three years at a moisture content of about 12 per cent. The experiments will be carried on so long as the fungi remain viable.

Work in co-operation with the Biochemistry Department of the London School of Hygiene and Tropical Medicine on the metabolic products of wood-destroying fungi has been continued, and the antibiotic activity of a number of species of these fungi has been examined.

Laboratory Testing of Wood Preservatives

Numerous requests from manufacturers for standard tests on their proprietary wood preservatives were received, and all the products submitted were tested according to British Standard Specification 838. The resistance to decay of wood treated with high concentrations of certain fire-proofing compounds has also been tested and found to be very much higher than that of untreated wood.

Experiments have been started to determine the effectiveness and rate of penetration across the grain in wood of a number of volatile fungicides that could be used for the treatment *in situ* of timber beams infected with wood-rotting fungi. Frequently timber beams in buildings are found to be slightly infected with dry rot at one end, but still sufficiently strong to carry the loads involved. Where replacement of the main beam may be a difficult and costly undertaking, treatment *in situ* to prevent further development of the fungus may be worth while.

Resistance to Decay of Timber and Other Building Materials

Standard laboratory tests have been carried out to determine the resistance to decay of a number of new species of Empire timbers.

The toxicity of a distillate from the alcohol extract from wallaba (*Eperua falcata*) has been tested and found to be very high, being approximately equal to that of pure phenol. The presence of this material or its parent substance in the wood is no doubt partly responsible for the high resistance to decay of this timber.

Numerous samples of composite wallboards, as well as floor blocks and other synthetic building materials prepared from wood waste, have been received from the Building Research Station for testing against dry rot fungi. When the binder used is a urea-formaldehyde resin, itself resistant to decom-

[1] CAMPBELL, W. G., and PACKMAN, D. F. Chemical Factors Involved in the Utilization of Wood in Association with Metals. *Ministry of Supply, S. & T. Memo.* No. 8/47.

position, and is present in sufficient quantities, many of these materials show a high resistance to decay.

Tests have also been carried out on the resistance to moulds of samples of plaster and also of coconut fibre and other packing materials Routine testing of the resistance to microbiological attack of glues in plywood samples has continued.

Effect of Fungal Decay on the Strength of Wood

No information was available as to the effect of incipient decay on the tensile strength of wood, so experiments have been carried out using beech in the early stages of decay caused by fungi of the brown and white rot types. It was found that in a given period the reduction in strength brought about by the brown rot was twice as great as that brought about by the white rot. It is now planned to study the comparative effects of brown and white rots on the other strength properties.

The effect of blue stain caused by three different species of sap-staining fungi on the tensile strength of pine sapwood has been examined. It was found that a slight but significant reduction is caused when the staining is severe; the results have been included in a paper published in ' Forestry '.

Collection of Fungi

The collection of cultures has been maintained and new species added to it. Numerous requests for cultures have been received, both from research workers in universities and from firms wishing to carry out tests on wood preservatives.

Further collections of wood-rotting fungi have been received from the forestry departments in British Guiana and Nigeria. Most of these have been identified with assistance from the authorities at Kew and have been incorporated into the herbarium. It has been possible to prepare cultures from some of them.

Dry Rot in Buildings

From the volume of advisory correspondence received, it is evident that dry rot is still causing a great deal of damage in property whose upkeep has been neglected during the war. An unusually large number of advisory visits has been called for to inspect affected property on behalf of other government departments and of local authorities, as well as private firms and individuals.

At the Building Research Station a Norwegian method of sterilizing brickwork infected with *Merulius lacrymans* by means of a $3\frac{1}{2}$ kW electric hot plate fixed on the wall has been tested in co-operation with the Laboratory. Blocks of wood infected with *Merulius* were built into a 14-inch brick wall and examined for the presence of living fungus after the heat had been applied. The temperatures at various depths in the wall were also recorded. It was found that complete sterilization was effected in the area covered by the plate, but that the heating and killing effect extended very little beyond its area. For a cost of 2 shillings to 4 shillings in electricity it is possible to sterilize an area of a $13\frac{1}{2}$-inch wall one metre square ; though this is appreciably cheaper than the cost of rebuilding it, the method is likely to find only a limited field of application in practice as the apparatus, as at present designed, is very heavy and awkward to fix in position.

Rot in Timber in Ships and Boats

Extensive rot in wooden linings in a refrigerated ship constructed only four years ago was investigated. It was found to have been caused primarily by condensation of moisture in the bilge plugs and coamings. The use of pressure-treated timber for these was recommended.

Numerous enquiries about the treatment and prevention of rot in small craft have been received and it is suggested that this problem should be investigated further. Large numbers of small craft have been laid up for years during the war and where storage conditions have been poor, much deterioration has occurred.

ENTOMOLOGY

General

Advisory and instructional work has continued to make big demands on the time of the staff throughout the year. Owing to shortage of staff, it has not been possible to resume work on the principal research projects which had to be suspended during the war, nor can any improvement in this connexion be foreseen until the position improves.

Experimental work has been confined to tests of insecticides and preservatives with particular reference to D.D.T. and Gammexane. The opinion of the Laboratory is frequently sought on the value of these new insecticides for the control of wood-boring insects. Preliminary experiments, to which reference was made in the report for 1945, have yielded results which, although promising, are not sufficiently complete to say whether or not these substances show any marked advantage over other materials hitherto used. The indications are that they will prove more effective as preservatives for preventing attack than as insecticides for eradicating existing infestation.

The main activities in entomology during the year may be summarized under the following headings :—

Lyctus *Powder-post Beetles*

Lyctus *Cultures*

Laboratory stocks of *Lyctus* powder-post beetles have again been built up after extensive depletion through infestation by the predaceous mite *Pediculoides ventricosus*. Experiments on the control of the mite were undertaken in which beta-naphthol and benzyl-benzoate were tested. The former proved so successful that the trouble has been virtually eliminated by its use in routine treatment of all culture vessels.

Lyctus *in Utility Furniture*

With the continued inclusion of untreated oak sapwood in the manufacture of oak utility furniture, there has been a further increase in infestation by *Lyctus*. Information and advice on methods of control have been requested by the Furniture Production Committee of the Board of Trade and by the British Furniture Trade Confederation. The Laboratory is represented on a sub-committee appointed by the Confederation to consider means of dealing with the problem which has become of increasing importance during the year.

Prevention of Infestation by Lyctus *in Sawn Timber*

Borax Treatment. Numerous requests have been received for particulars of the short-period borax dipping treatment for green timber, which earlier

work has shown to be effective in preventing *Lyctus* attack. In most cases objections were raised to the method because it involved heating the borax solution. A recent instance arose, however, in which, owing to serious trouble with *Lyctus* on a manufacturer's premises, a firm was prepared to set up the requisite equipment. English oak was treated and the Laboratory is keeping in touch with the application of this control measure on a commercial scale.

Tests with D.D.T. and Gammexane. An urgent need in *Lyctus* control, particularly for stocks of seasoned timber and for timber after heat sterilization, is a simple and inexpensive superficial treatment which would prevent attack or reinfestation. Results of Laboratory tests with D.D.T. and Gammexane have indicated that these substances are worth trial for this purpose under field conditions, particularly in view of the recent increase in infestation by *Lyctus* in English oak. Resulting from discussions with the Chemical Research Laboratory and with Dr. H. Martin and Dr. H. G. H. Kearns of Long Ashton Horticultural Research Station as to the formulations of D.D.T. and Gammexane likely to be most suitable for the purpose in view, a large-scale experiment was started during the year at the Laboratory in which logs of oak, ash and elm of commercial size sawn " through and through " were treated with these substances, applied as oil solutions or as oil-water emulsions, supplied by the Chemical Research Laboratory. Throughout the summer, natural infestation of treated and untreated control logs was allowed to proceed and was supplemented by artificial infestation under wire gauze cages. The weathering properties of the insecticides in relation to their durability under conditions likely to prevail in timber yards are of interest and are included as an important part of this investigation.

A preliminary examination of a few boards has indicated that the treatments are likely to have been effective in preventing *Lyctus* attack during 1946, but results are as yet inconclusive and the experiment is continuing.

Laboratory Tests of Insecticides and Preservatives

This work has been chiefly concerned with an evaluation under laboratory conditions of pentachlorphenol and various formulations of D.D.T. and Gammexane for the prevention of attack by *Lyctus* powder-post beetles. Experiments are incomplete, but the following is a brief summary of the work in progress during the year :—

Pentachlorphenol

A series of experiments to prevent infestation by *Lyctus brunneus* has been undertaken to investigate the cause of failure of short period (1–3 minutes) dipping treatments of English oak sapwood in a 3 per cent solution of pentachlorphenol in kerosene and other solvents. Such treatments have been recommended in other countries for the control of *Lyctus*. The results of the recent work at Princes Risborough have shown that vacuum impregnation of English oak sapwood with a 3 per cent kerosene solution of pentachlorphenol did not prevent egg-laying or hatching, but that the larvae of *Lyctus brunneus* died soon after hatching. It seems probable that the failure of the short period dipping treatments was due to insufficient penetration of the pentachlorphenol solution.

D.D.T. and Gammexane

(i) *Insecticide Tests.* Some preliminary experiments were carried out to determine the value of 2·5 per cent solutions of D.D.T. and of Gammexane in a standard organic solvent, as insecticides for the treatment of insect-infested timber ; oak sapwood attacked by *Lyctus brunneus* was used in these tests.

It is, however, not yet possible to say, from results so far obtained, whether such solutions show any increase in toxicity or effectiveness solely as insecticides in comparison with other materials normally used for this purpose.

(ii) *Preservative Tests.* An extensive series of experiments was started to determine the effect on the common wood-boring beetles of contact for varying periods with surfaces treated with different concentrations of D.D.T. or of Gammexane. Toxicity data have been collected from this work for the powder-post beetle, *Lyctus brunneus*, the common furniture beetle and the death-watch beetle, but a full comparison of the effects of these insecticides on the three species has not yet been made. In general, however, all three insects showed the same type of reaction to contact with these insecticides as has been described for other species which are not wood-borers.

The effect of the addition of 2 per cent D.D.T. to a polish applied to the surface of timber infested by *Lyctus brunneus*, or by the common furniture beetle, in relation to emergence of the insects, has been investigated. It was found that, although emergence was not entirely prevented by such a treatment, a high percentage of the beetles failed to complete exit holes and died within the wood.

The possible value of a superficial brush application of D.D.T. in a highly volatile solvent for preventing emergence of beetles is also being explored. The results so far obtained are complicated by the slight penetration and the toxic effect of the solvents which were used, but they are sufficient to show that emergence can be reduced by surface deposits of this insecticide applied in such a way.

Pinhole Borers (Scolytidae and Platypodidae)

Experiments have been begun in co-operation with the Forest Department, Gold Coast, to investigate the possibility of preventing infestation by pinhole borers in newly felled logs by treatment with various formulations of D.D.T. and Gammexane. Details of the work involved have been discussed with forest officers on leave, and, at the request of the Forestry Adviser, Colonial Office, arrangements are being made for extending this work to other colonies, e.g. British Honduras and Malaya, where these insects are prevalent. Supplies of the insecticides have been provided by Imperial Chemical Industries, Limited, who are co-operating in the experiments.

The Common Furniture Beetle (Anobium punctatum)

This insect has continued to be the subject of a large number of enquiries, being responsible for nearly half the total of advisory letters dealt with during the year. It has become increasingly important as responsible for damage to the sapwood of structural timbers, softwoods and hardwoods, and it often causes serious injury to certain types of plywood. Attention has been directed by outside bodies to the prevalence of this type of insect attack in plywood, and the need for a full-scale investigation on methods of prevention and control has been discussed with the Laboratory. Such work involves a co-operative investigation between Entomology, Composite Wood and Wood Preservation Sections but, owing to lack of staff, it has not yet been possible to make a start with this urgent investigation. In the meantime, however, collection of information has continued on incidence of attack and upon the susceptibility of timbers and of different types of plywood to infestation. This work included investigations of widespread attack on a municipal housing estate in the south of England, and of severe damage in the north in a large store of wooden pattern blocks used for printing textiles.

Miscellaneous

The Laboratory was represented at a meeting convened by the Forestry Commission to enquire into the risk of introducing into this country insect pests of trees and timber in spruce and pine logs from Germany and to consider methods of prevention and control.

SEASONING

Kiln-seasoning (*Orthodox Methods*)

Apart from delays in obtaining timber for the large kilns, these units have been in operation throughout the year. In them have been dried loads of 4-inch iroko planks for electrical equipment, $1\frac{1}{4}$-inch oak for Utility furniture and willow clefts for cricket bats. The intermediate kilns have been used for the drying of loads of Empire timbers such as essia, celtis and afzelia.

The small model kilns have been used continuously for a number of purposes. including the seasoning of Empire and foreign timbers, briar root blocks for pipes, blackwood billets for musical instruments and, for the Fuel Research Station, low density plastic material.

It is intended, wherever possible, that information obtained from small-scale kiln runs shall be supplemented by information obtained from the drying of similar material in the larger kiln units.

Seasoning (*Novel Methods*)

Considerable attention has been given to the possibilities of seasoning wood by radio-frequency heating, and a 5-kW high frequency generator has recently been installed so that tests on these lines may be undertaken.

In connexion with this method and with a Swiss patented method of drying by means of induced temperature gradients, wood samples have been dried by exposing one face to cool, humid air while the other face has been kept in contact with an electrically heated copper plate. Tests of this nature have indicated that accelerated drying may result from heating the core or centre of a board by radio-frequency methods and cooling the surfaces, but that a temperature gradient from face to face is not likely to prove very effective.

Tests have also been carried out on the so-called " Irsay " vacuum drying process (patented) in the large-scale plant erected at Hull by Messrs. Tarran Industries Limited. The tests demonstrated that $2\frac{3}{4}$-inch beech could be dried satisfactorily from 90 to 35 per cent moisture content in a period of $1\frac{1}{2}$ days. These promising results, however, were offset by the fact that difficulties and drying times increased rapidly when once the fibre saturation point has been reached, and there was some evidence to indicate that such rapid drying could not be achieved on refractory hardwoods such as oak without appreciable degrade. Other tests have been undertaken to determine whether timber may satisfactorily be seasoned with the aid of chemicals, such as urea, or solvents, such as acetone, and whether electrical strip-heating in vacuo would prove effective. None of these methods has to-date shown great promise, and the disadvantages to be associated with most of them appear to outweigh the possible advantages.

Moisture Tolerances

Ideally wood for any specific purpose should be dried to a moisture content corresponding to the average of the yearly fluctuations to which it may be subjected in service. Thus if it is known that the moisture content of a piece of furniture will fluctuate between say 10 per cent and 14 per cent the ideal moisture value for the seasoned wood would be about 12 per cent. In

practice this ideal may be exceeded without the subsequent shrinkage that must result necessarily proving very detrimental, especially where comparatively narrow pieces are to be used.

In order to investigate the moisture tolerance permissible in Utility type furniture, tests have been carried out in co-operation with the firm of Messrs. Harris Lebus whereby articles of furniture were manufactured from oak, kiln-dried at the Laboratory to moisture-content average values of 20 per cent and 16 per cent respectively, and after manufacture were kept in conditions calculated to bring the average moisture content of the wood finally to about 12 per cent. The furniture was then examined by experts and was graded according to visible defects, outward appearance, fit of drawers and quality generally.

The findings were that wood at a moisture content higher than 12–14 per cent was liable to give trouble during the actual manufacture and assembly, but that subsequent troubles, although sometimes appreciable, did not necessarily render the finished product unserviceable. A higher moisture content could, with impunity, be allowed for the table-leg squares and doubtless also for straight-grained wood having less shrinkage than oak.

Miscellaneous Seasoning Items

Several moisture meters of different types have been calibrated and tested, and all, whether of the resistance or of the capacity-measuring type, appear to be subject to about the same degree of error.

Co-operative work with the Timber Control continues, and numerous commercial kiln-installation schemes have been examined and commented upon at their request.

WOOD BENDING

Much of the work on wood bending has been concerned with the determination of the limiting radii of curvature of laminae and plywood, both in the untreated state and also after receiving various forms of softening treatment.

Attention has been given to the development of plywood having exceptional bending properties, and work upon this continues.

A considerable amount of work has been done in connexion with the bending of solid timber, and consignments of Canadian rock elm and white elm have been converted and tested.

A serious deficiency in work on wood bending both scientific and industrial is the almost complete lack of literature. It was therefore decided to afford time for the preparation of a comprehensive treatise on the bending of wood both in solid and laminated form. The draft of this book has been completed and it is ready for printing.

WOODWORKING

Standard tests were carried out on Monterey cypress (*Cupressus macrocarpa*) from Sussex, cupiuba (*Goupia glabra*) from Brazil and celtis (*Celtis soyauxii*) from Nigeria, to determine their working qualities and the optimum working conditions. Experimental work was limited to minor investigations in rip-sawing, planing and boring operations and to tests on hand-pruning saws. Theoretical studies have been concerned with the cutting conditions required for certain classes of refractory timber and processed wood, the mechanics of sawing, and calculation of the stresses in cutters on revolving blocks.

COMPOSITE WOOD

Properties of Adhesives

The preparation and exposure of panels in the long-term project for testing plywood adhesives were completed early in 1946, and the monthly inspection and periodic testing are now a well established routine. An analysis of the results obtained during the first twelve months of this ten-year experiment will be ready by March 1947.

The plywood panels used in this experiment have been made of beech, a species admirable for this particular purpose because of its large movement with moisture change which imposes heavy stresses on the glue lines. It is recognized, however, that some of the adhesives which perform indifferently with beech may be satisfactory with a less exacting timber, and tests on these glues are being duplicated using plywood of lime or gaboon. Some of this material was prepared and exposed during 1946, and completion of the project awaits the delivery of fresh timber supplies.

For trials on assembly glues, which are used at normal temperatures for joining parts of structures, many types of test-unit are needed because of the numerous kinds of joint involved. As a beginning, a plywood-clad frame and a laminated beam have been selected. With the former, beech or Douglas fir plywood is glued to both faces of a softwood frame which forms one side of a long hut of triangular section (Figure I).* One side of the test unit is thus exposed to weather and the other protected from sun and rain but in contact with outdoor air. In fixing the plywood to the frames, various types of glue have been used, and different methods employed for applying the necessary pressure. The adoption of several ways of protecting the edges of the glued areas from direct weather, such as by paint or by cover-strips, adds to the scope of the experiment, and the two ply-clad faces of the frames themselves serve for comparative purposes. Nearly fifty frames have been under observation since the middle of the year.

The second test-unit, the laminated beam, will test in large joints the relative durability of the different types of glue. Casein glue, for example, fails very quickly in plywood exposed to severe weather conditions, but it is thought that in large joints into which moisture cannot readily penetrate, its performance may be satisfactory for long periods. The beams will be loaded so as to impose a steady shear stress on the glue lines, and will be exposed both to weather and also to the conditions of a ventilated, unheated shed.

Ageing tests on specification-type glued joints of the " close contact " and " gap " types continue as a routine, and some results over four years are now available.

An investigation into the effect of the moisture content of wood on its gluing characteristics has been started. Tests on beech joints of the type specified in British Standards 1203 and 1204 showed that the strength of " close contact " joints (that is, those with a glue-line thickness not greater than five-thousandths of an inch) is considerably reduced when wood with a moisture content greater than about 13½ per cent is glued with a synthetic resin of the phenol-formaldehyde type. With a urea-formaldehyde resin and casein the critical figure was 20 per cent. Failing loads slightly above average resulted from the use of wood at 4½ per cent moisture content. The effect on " gap " joints (those with a glue line fifty-thousandths of an inch thick) was not so marked but reduction of strength occurred with both the urea and phenol-formaldehyde resins at about 13½ per cent moisture content.

The practical significance of these effects was investigated by making large blocks 6 inches thick with 1-inch boards and employing the same three types

* Facing page 38.

of adhesive, viz. casein, urea-formaldehyde and phenol-formaldehyde. Both beech and Corsican pine at moisture contents of approximately 7, 12 and 20 per cent were used, the grain of adjacent boards being so arranged as to produce maximum movement-stresses. The adhesion was tested by subjecting the blocks to drying and wetting cycles. Failure in the glue line resulted to a greater or less degree with the hardwood at all moisture contents, but with the softwood splitting occurred entirely in the wood. At the high moisture-content the urea-formaldehyde resin was much the best but at 7 per cent and 12 per cent the urea- and phenol-formaldehyde were adversely affected to an equal extent by the test, the casein much more so. The results indicate the possibility of a maximum thickness of lamination for each moisture content and this will be investigated in the near future.

A contemporary and independent mathematical treatment of this subject[1] leads to the conclusion that thin laminations are better for gluing than thick ones and that wood species with low elastic moduli are better than those with high moduli.

At the request of the Ministry of Aircraft Production, which had issued instructions for the repair with synthetic resin adhesives of wooden aircraft originally glued with casein, tests were made to check the efficacy of the method using various proprietary makes of adhesive. The tests showed that with most of the adhesives reasonably satisfactory joint strengths could be obtained only by removing all visible casein by sanding and then coating with the appropriate hardener before applying the glue ; even so the failing loads were rather below average.

Adhesive Makers' Panel

The informal body known as the Adhesive Makers' Panel, which was convened in 1945 to foster relations between the Laboratory and industry, continues to meet thrice yearly. It is proving an excellent medium for the exchange of information, and the suggestions received assist greatly in planning the research programme so as to be of maximum value to industrial glue-users. A bulletin[2] which was prepared in collaboration with the Panel has been published.

Special Heating Methods for Setting Glues

The application of heat for accelerating the setting of synthetic resin glues is now widely practised as a means for increasing the output from clamps and jigs, and new methods of applying the heat are coming into use. The studies on radio-frequency and infra-red heating have continued, and work on the latter has now been taken to the point when it can be adapted for industrial application.

Infra-red radiation provides a method of rapidly raising surface temperatures, but the slower process of ordinary thermal conduction must then be relied upon to carry the heat from the surface to a glue line beneath. Where, however, the edge of the glue line is exposed or where the intervening layer of wood is thin, as in the case of a face veneer, it is apparent that rapid heating of the glue line could be effected ; and, in fact, owing to the beaming characteristic of the radiation, which allows inaccessible regions and irregular surfaces to be heated, it appeared that there might be industrial applications in which the process could show to advantage in either speed or convenience

[1] DIETZ, A. G. H., GRINSFELDER, H., and REISSNER, E. Glue Line Stresses in Laminated Wood. *Trans. Amer. Soc. mech. Engrs.*, 1946, **68**(4), 329–335.

[2] KNIGHT, R. A. G. Requirements and Properties of Adhesives for Wood. *For. Prod. Res. Bull.* No. 20. (H.M.S.O., 1946, 7*d.* post free.)

over conventional methods using a heated element between the work and the pressure device.

The aim of the investigation was therefore to derive basic data on the behaviour of wood assemblies under infra-red radiation, and then to apply the results to a few practical gluing problems, but it was found necessary first to investigate the properties of the generating plant which had been selected. This was of the commercial incandescent electric lamp type, originally designed for drying painted metallic panels ; but whereas in these conduction and other factors help to even out the effects of irregularities in the radiation, for satisfactory glue-setting the radiation itself must be uniform.

The apparatus consisted of trough-shaped reflectors carrying banks of nine 250-watt infra-red lamps ; these units could be mounted in racks at any desired spacing, and arranged to direct their rays on to a receiving plane at any selected distance ; the apparatus was also provided with side reflectors. Figure 2 shows diagrammatically the arrangement used and also the nomenclature. A typical diagram of the temperature distribution on a black-painted

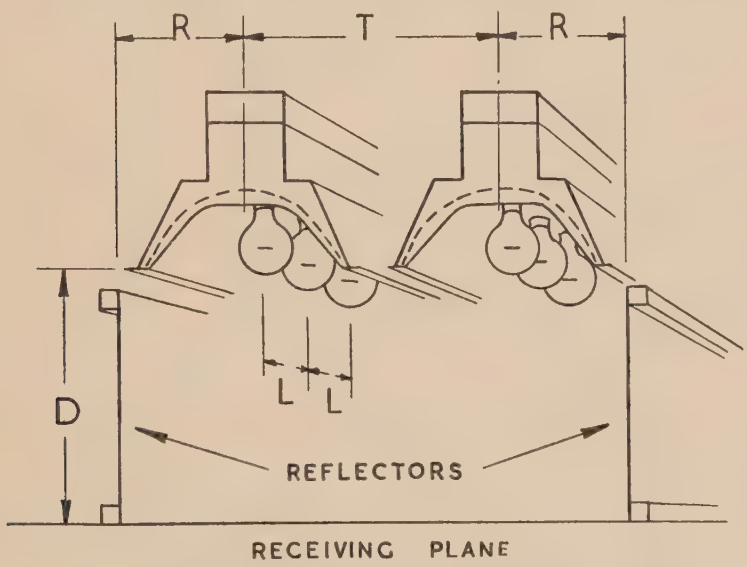


FIG. 2. ARRANGEMENT OF INFRA-RED LAMPS, WITH KEY TO SYMBOLS

plywood surface under a single trough is shown in Figure 3, from which it may be seen that uniformity is not maintained over the full width of the trough unit ; when, however, units are mounted side by side, or side reflectors used, the overlapping of the fringes of the radiation patterns gives a substantially uniform heat over any desired area ; and after systematic studies of the temperature distributions it was possible to set up the units and reflectors at such values of R, T, D, and L as to give uniform heating of any desired intensity.

It was found preferable to determine distributions by temperature measurements on a receiving surface, rather than by actual measurements of radiation intensity, but average values of the latter were found by measuring the rate of heating of a copper block, 0·25 in. (6·3 mm.) thick, insulated on the back and sides and painted black on the exposed face. Under suitably arranged trough

units intensities up to 350 watts per square foot (5·4 cal. per minute per square centimetre) were recorded. A special concentrating type of reflector carrying a single 250-watt lamp gave intensities up to 1,300 watts per square foot (20 cal. per minute per square centimetre) over an area of a few square inches.

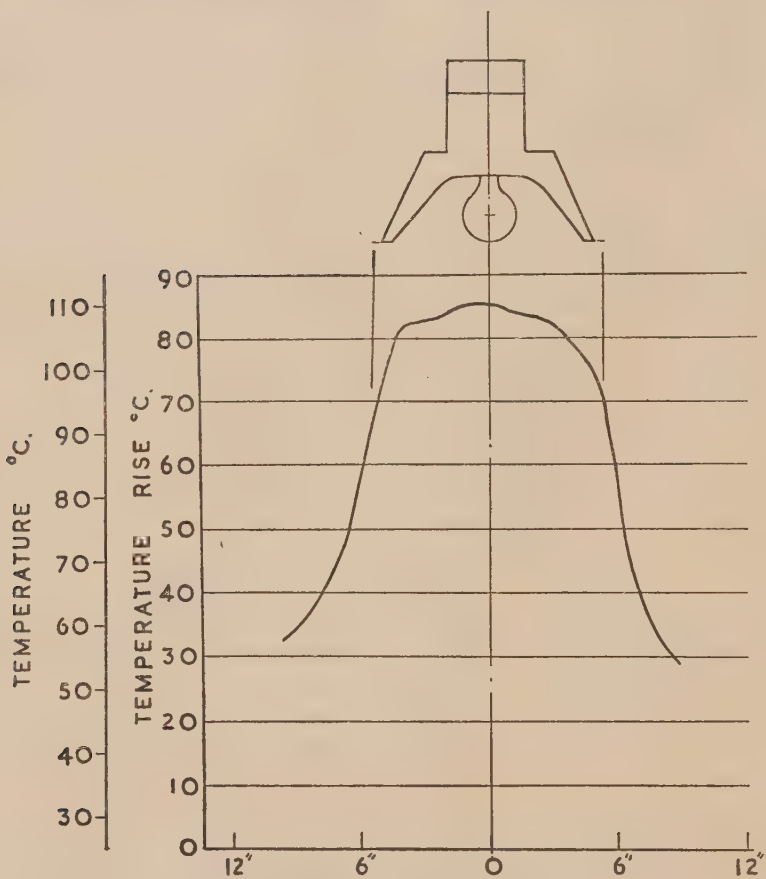


FIG. 3. TEMPERATURE DISTRIBUTION BENEATH TROUGH REFLECTOR

The surface temperatures reached by timber and plywood exposed to the radiation were found, as was expected, to vary widely with factors such as colour and orientation, as well as with the thickness and nature of underlying material. A bare wood surface undergoes only 50 to 60 per cent as great a rise in temperature above atmospheric as does one which has been painted black, but there is comparatively little variation between the bare wood of different species ; also a large plywood panel becomes hotter than a small one owing to convection effects, and for a similar reason a vertical surface becomes less hot over the lower half than a similarly treated horizontal one.

Loss of moisture during heating was not observed to cause excessive surface-cracking of the timber within the time required for a gluing operation, but it caused a very great increase in the heating time, which was arbitrarily defined as the time required to reach a temperature of 5°C. below the equilibrium temperature. For instance, a beech panel 0·25 in. (6·3 mm.)

thick took about 10 minutes to heat under various intensities of radiation if it had first been oven-dried; but starting at a normal moisture content of 12 per cent it took 15 minutes to heat to a final temperature of 55°C., and under more intense radiation, nearly an hour to reach 110°C. If, however, the egress of moisture was prevented by gluing very thin veneers to the panel with a phenolic resin adhesive, the latter period was reduced to 20 minutes.

Thinner panels naturally heated more quickly, but not proportionately so, and they did not reach so high a final temperature on the exposed face. The effects of thickness on rate of heating and final temperatures did not show beyond a thickness of about 0·6 in. (1·5 cm.), but at that point the heating time was of the order of one hour even if moisture barriers were present. This suggested that it would not generally be possible to make use of final temperatures in practical applications where the process is employed for speed ; yet it is not always satisfactory to work on the sloping part of the heating curve, for there is then always the danger of overheating. It is, however, quite practicable to heat at high intensity for a short time and then to reduce the intensity by switching off a suitable proportion of the lamps when the working temperature is reached, as illustrated in Figure 4, which relates to working temperatures of 60°C. and 80°C.

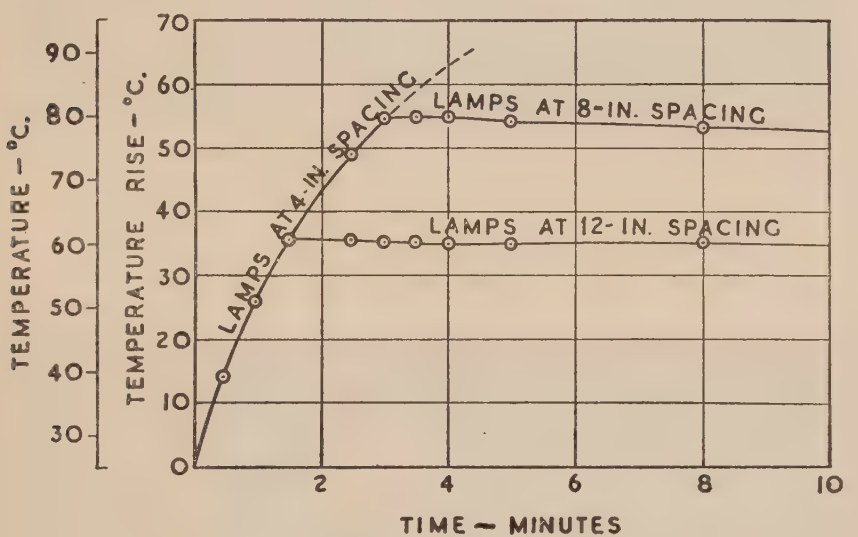


FIG. 4. EFFECT ON TEMPERATURES OF SWITCHING FROM HIGH TO LOW POWER

One practical application of the results was to the accelerated setting of the glue in laminated beams with the object of shortening the time during which the press was occupied ; for this purpose a urea formaldehyde glue was used, which would have required about 4 hours to set at room temperature (20°C.). The beams consisted of eight $\frac{1}{2}$-inch laminae 4 inches wide arranged in a screw press and irradiated on each side by a trough reflector unit ; the heating thus induced accelerated the setting of the edges of the glue lines, and this enabled the beams to be safely removed from the press in a comparatively short time, after which the inner parts of the glue lines could complete their setting at room temperature. Each beam was exposed to infra-red radiation for a certain period, left under pressure without irradiation for an equal period, and then removed and immediately split open for examination of the glue lines.

The appearance of the resulting joints is illustrated in Figure 5, which relates to exposure times of 5, 10 and 20 minutes. In one case the sides of the beam were painted black, but this had less effect than had been expected.

Another problem attacked was the gluing of small attachments, resembling the corner blocks used in furniture manufacture, to larger surfaces without the use of clamps. This was effected by strongly heating one of the surfaces for about ½ minute with the concentrating lamp (see Figure 6), meanwhile applying a very fast setting glue to the other surface ; on assembling the joint the stored heat in the wood was sufficient to set the glue in a further half-minute or less, thus allowing hand pressure to be used.

Another application of radiant heat is in the veneering of curved surfaces. The use of tensioned strips of metal for applying pressure in such cases is a common practice, and one method which has been used for applying heat is to pass a current at low voltage through the strips. If, however, the strip is painted black, to raise the absorption of energy to a maximum, it can conveniently be heated by directing infra-red radiation on to its surface. Tests were carried out in which a strip of beech veneer 0·02 inch thick was glued to a spruce block, 8 inches long and 1·5 inches wide, the upper surface having a 12-inch radius of curvature, the tension strip being of 30 S.W.G. brass, painted black. Two varieties of urea-resin glue were used and these could be satisfactorily set in 3 to 5 minutes.

These applications are sufficient to demonstrate that for certain kinds of work infra-red heating can provide a comparatively inexpensive solution to glue-setting problems. A report[1] on the investigation has been published.

The most promising application of radio-frequency heating for glue setting in industry has been found in ' assembly ' work, as in furniture construction, where many of the glue lines are of such a depth that they cannot be heated by conventional methods. In such applications it is often possible to adopt the so-called ' glue line ' method, i.e. passing the radio-frequency current along rather than at right angles to the glue line. This method results in a highly selective heating of the glue as compared with the wood, giving the advantages of considerable power economy, extremely rapid glue setting, and a relatively cool assembly to remove from the jig. Unfortunately the radio-frequency method does not lend itself well to theoretical treatment and very little is known about the effects of the many factors involved. Attention has therefore been confined to the " glue line " aspect in the investigations carried out so far. The work has been of an exploratory nature, and has consisted in determining in small-scale tests the relationship between applied voltage and setting time at various frequencies, and the effects of such factors as thickness of glue-spread, type of glue and of timber, delays between spreading the glue and applying heat, and the introduction of air gaps between the electrodes and the work. In default of a means of measuring radio-frequency power, all results have been expressed in terms of radio-frequency voltage.

When each factor had been investigated on the small scale the results were subjected to confirmatory tests in the manufacture of laminated beams 6 feet long by 3 inches square. Using a cold-setting urea resin adhesive these could be bonded within one minute. In smaller assemblies setting-times of only a few seconds were achieved, but further experiments are needed to determine whether or not the glue deteriorates at all in the process.

The work has shown that for the most efficient use to be made of the available power :—

(a) Heating cycles of the order of 1 minute or less are essential.

[1] Lacey, P. M. C., and Howe, H. A. Infra-red Heating for Setting Glue in Wood Joints. *Wood*, 1946, **11**(12), 345–348.

FIG. 1. LONG-TERM DURABILITY TESTS ON ADHESIVES : THE PLY-CLAD FRAME TEST UNIT

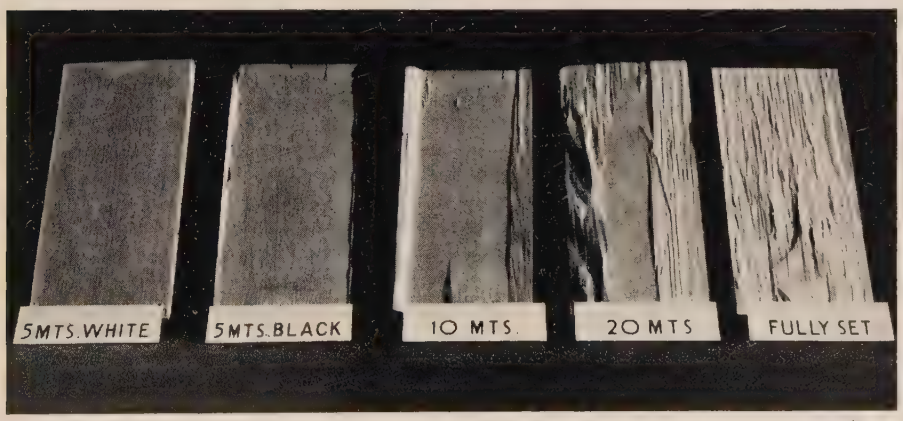


FIG. 5. EXTENT OF GLUE-SETTING IN JOINTS HEATED BY INFRA-RED RADIATION APPLIED TO THE EDGES

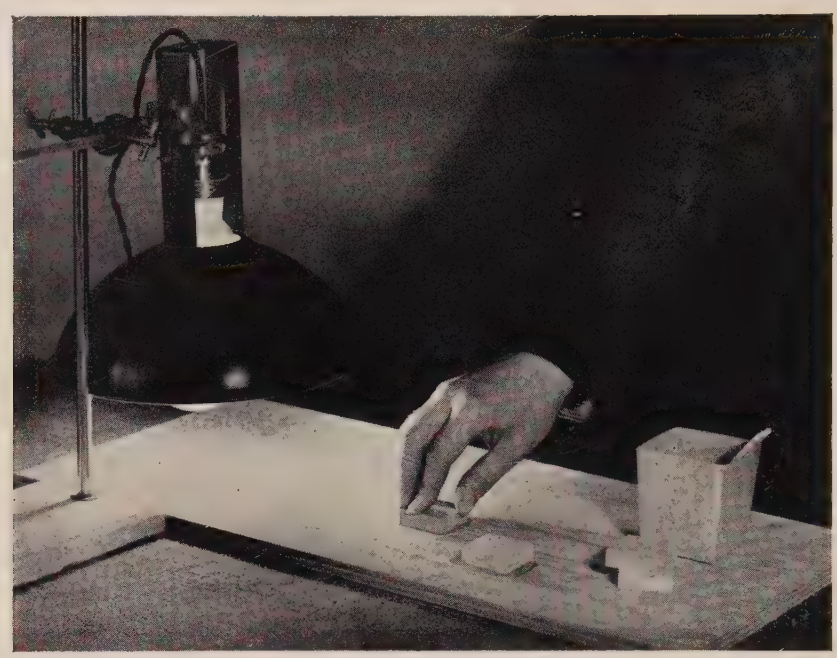


FIG. 6. GLUING OF SMALL BLOCKS TO LARGER AREAS BY THE PRE-HEATING METHOD

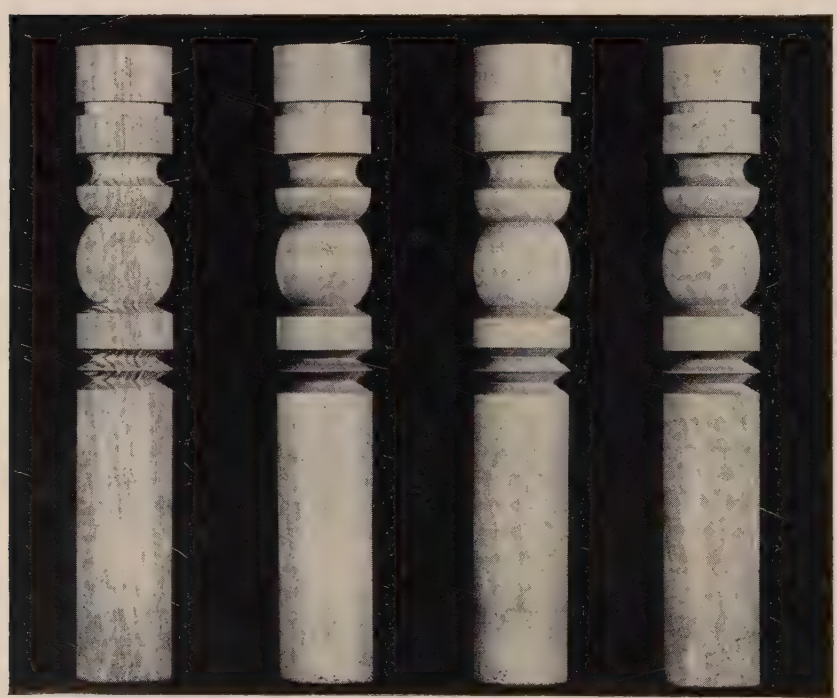


FIG. 7. SAMPLES OF WOOD TURNED AFTER IMPREGNATION WITH ROSIN-WAX

(b) In contrast to other applications of radio-frequency heating, when using wet resin glues a low frequency should be applied (say 1 to 2 megacycles per second) as this improves the selective heating of the glue.

(c) Glues of high radio-frequency conductivity should be used, spread relatively heavily and with the minimum of delay between spreading and pressing.

It does not appear to be essential to make the extremely difficult measurement of the rapidly varying temperature of the glue line under treatment, and it is probably more satisfactory to work on the basis of the electrical conditions applied to the joint, viz. the power and the voltage. The investigation has shown the importance of knowing the former quantity, and work is in hand to evolve a method of on-load measurement of the radio-frequency power delivered into a given load.

TIMBER MECHANICS

Claims of advisory work and shortage of staff continue to hold up the development of new projects.

Standard Tests

Standard tests have been made on a number of Empire species new to commerce.

The Use of Timber in Building

Further thought has been given to the design of equipment for research on floors and roofs for low-cost housing, but it has not yet been possible to start experimental work.

For manufacturers of pre-fabricated houses tests have been made of a roof truss for an " ultra light-weight " roof, and of a flooring unit, both of which subsequently went into large-scale production. Tests were also made by request on a number of built up beams and on built up scaffold boards.

Considerable assistance was furnished in connexion with the revision of the Ministry of Health Memorandum on Timber Economy in Building, including the preparation of revised tables for sizes of joists, rafters, etc.

Further analysis has been made of the results of tests carried out before the war to determine the relationship between strength and incidence of knots in Baltic redwood.

Timber Floors

Abrasion tests have been carried out for the Ministry of Works to assess the resistance to wear of a number of proposed finishes for concrete floors, including wood-waste boards, thin wood strips and wood veneer. A number of wood-waste boards and a paper/plastic floor panel have been tested for manufacturers.

Packaging

Ad hoc investigations have been carried out, on request, as follows :—

(i) Several series of tests of collapsible and non-collapsible boxes.

(ii) Tests of numerous samples of fibreboard for the New Zealand Department of Agriculture in London, in connexion with the placing of contracts for fibreboard boxes for the export shipment of butter.

(iii) Tests to determine the moisture content/relative humidity characteristics of fibreboard, for a wireless manufacturer.

(iv) Tests of the bursting strength and moisture transmission of building papers.

(v) Tests of moisture transmission of paper foil laminates.

(vi) Tests of fibreboard containers for wireless sets for home and export markets.

(vii) Tests of a new type of fibreboard box for the shipment of citrus fruit.

(viii) Tests of a pack for 57/1/4/7 lantern projectors and of a wire mesh crate for bicycles, for the Ministry of Supply.

Miscellaneous Investigations

A series of tests was made on request to determine the influence of a fire-proofing treatment on the impact strength of Douglas fir.

For the Board of Trade a series of tests has been made of Utility dining chair seats. Further work on this subject was undertaken at the request of a furniture manufacturer. A patent metal dowel for use in furniture construction has also been tested for the Board of Trade.

WOOD PRESERVATION

The enforced shortage of timber during and since the war has emphasized the need for using the limited supplies to the best advantage and the importance of preservative treatment for all timber used under conditions favourable to decay. During the war years this question of wood preservation received much publicity, which is now being reflected in the large number of enquiries received at the Laboratory and the more general interest taken in this subject by supplier and user alike. This interest has indeed grown to such an extent that it has been considered that the time is opportune for the preparation of standard specifications for wood preservatives, and the Laboratory has been able to give assistance to the appropriate committees of the British Standards Institution in the preparation of standards for preservative materials and methods.

Transmission Poles

Owing to the shortage of redwood (Scots pine) poles imported from the Scandinavian countries, it has been necessary to fall back on other sources of supply. For this reason species such as spruce and larch, which were not extensively used when redwood was readily available, have had to be employed in increasing amounts. Both these species differ from redwood in being resistant to impregnation with creosote. Experimental treatments have therefore been made to determine the most suitable methods for impregnating spruce poles and it has been found that it is possible to treat spruce by the Rueping process to give satisfactory penetration of the creosote and with a minimum of subsequent " bleeding ". It has been shown that in the treatment of refractory timbers such as larch or spruce it is essential to carry out the treatment with the creosote at a relatively high temperature if satisfactory results are to be obtained.

Tests have also been carried out on the treatment of poles with preservatives other than creosote and a number of poles treated with a water-borne preservative have been put under test in the line.

Rosin-wax Impregnated Wood

It is often desired to modify certain physical properties of wood either to impart certain exceptional ones or more often to modify a readily available or

cheap wood to provide a substitute for a scarcer or more valuable wood having special properties. In recent years, much attention has been given to the impregnation of wood with synthetic resins, and a number of treatments have been most successfully applied, particularly in the case of products built up from impregnated laminae, but unfortunately the impregnation of wood with synthetic resins is not a cheap process. It appeared that the impregnation of wood with various natural oils and resins might yield a cheaper product, and one mixture which has been used has shown sufficient promise to warrant attention being called to it as a relatively cheap and effective substance for "densifying" wood for specialized purposes where weight and water-resistance are of importance.

Treatment consists of impregnating the wood with a solution of rosin in paraffin wax. Solutions of these two substances are quite fluid at temperatures of about 180°F. and can be injected into wood under pressure by the same type of process as is used for the preservative treatment of wood. They appear to be stable and can be used repeatedly without apparent deterioration. They are pale to dark brown in colour according to the grade of rosin employed, and if necessary they can be coloured to a variety of shades with wax-soluble dyes or other materials. Wood treated with this rosin-wax solution machines and turns remarkably well as may be seen from Figure 7, which shows typical specimens turned from treated samples of Corsican pine, maple, beech and hornbeam. The treatment also reduces the rate of moisture absorption and thereby tends to stabilize the dimensions of the wood. Figure 8 shows the periodic swelling and shrinkage which occur with two matched beech specimens of 2 inches by 2 inches section and $\frac{1}{2}$ inch long, one fully impregnated and one untreated, when subjected alternately to humid and dry air. It will be seen that the dimensions of the treated block change more slowly than the untreated one ; and, moreover, the total dimensional change over the complete cycle is less. This improvement in dimensional stability is also evident when the same pair of specimens are immersed in water, as will be seen by referring to Figure 9, although it has not yet been established to what extent the treatment modifies the eventual relationship between moisture content and humidity. From the experiments so far conducted, it will obviously tend to damp out the effect of short-period fluctuations of humidity

Although in some cases a light impregnation treatment may serve a useful purpose, best results will generally be obtained by a heavy impregnation of the wood. This means, of course, that its density will be increased considerably, so that fully impregnated wood may weigh from 55 to 70 lb. per cubic foot according to the species. The necessity for heavy impregnation limits the application of the treatment to permeable wood such as beech, hornbeam, lime, sycamore and alder, together with the sapwood of practically all hardwoods and softwoods. This limitation, however, is common to most impregnation methods for modifying the natural properties of wood. The cost of the rosin-wax mixture is of the order of 6d. per lb. at the present time (1946), so, for example, the cost of completely impregnating a permeable wood like beech would be about 12s. 6d. per cubic foot for the impregnant alone. At first sight this may appear high, but as the treatment does not cause any appreciable change in the dimensions of the wood, it can be applied to finished or semi-finished articles, thus eliminating practically all waste during conversion, so that the cost applies to the net volume of the articles treated. Where complete impregnation is not required the cost would be much lower, depending on the amount of rosin-wax absorbed. Splitting or distortion is not likely to occur during treatment unless the wood is originally defective or insufficiently seasoned. The solution is readily injected by an orthodox

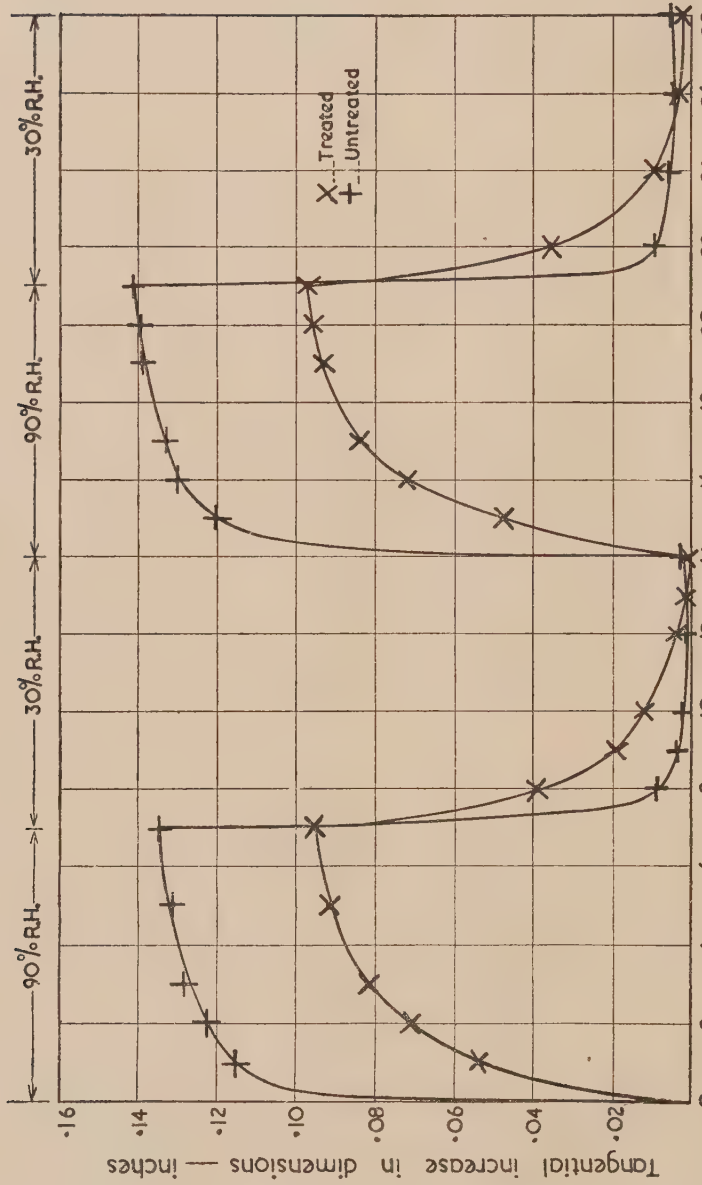


FIG. 8. EFFECT OF RELATIVE HUMIDITY ON DIMENSIONS OF WOOD IMPREGNATED WITH ROSIN-WAX

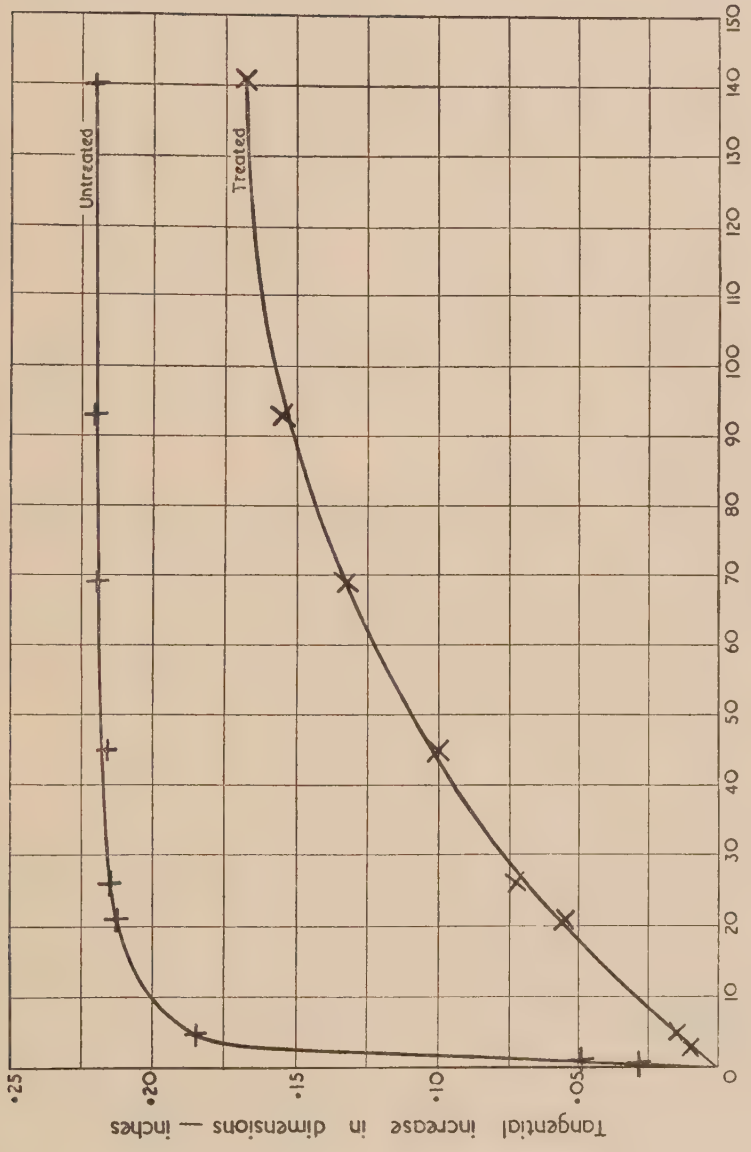


FIG. 9. EFFECT OF IMMERSION IN WATER ON DIMENSIONS OF WOOD IMPREGNATED WITH ROSIN-WAX

vacuum-pressure treatment, which can be conveniently carried out in any type of impregnating plant capable of withstanding a reasonable vacuum-pressure cycle and which incorporates facilities for maintaining the solution at a temperature of about 180°F. Before injecting the solution, it is desirable to pre-heat the wood to near the working temperature of the rosin-wax mixture so that the solution does not solidify in the wood before it has been properly impregnated. It is also necessary to keep the charge hot and to allow it to drain thoroughly after impregnation to avoid congealing of the solution on the surface.

The solution with which the experiments were carried out contained 60 per cent of rosin and has a freezing point of about 130°F. Rosin and paraffin wax are apparently completely miscible so that the solution strength can be varied widely, but the properties of alternative solutions have not yet been examined in detail. As the rosin content increases, the freezing point decreases slightly, but the solutions become more viscous and thus would require a higher working temperature. Preparation of the solution requires a little care to avoid thermal decomposition of the rosin, and the best method is to heat the paraffin wax to not more than 230°F. and then dissolve the rosin ; if the rosin is melted separately some decomposition may occur. Oil-soluble dyes may be added to the solution to give different colours, or bitumen to give various shades of brown. It is most likely that the solution itself has a preservative effect on the wood, but there would be no difficulty in adding toxic material if considered necessary.

The chief and most obvious disadvantage of wood treated with rosin-wax is its high combustibility. Both of the impregnants are much more inflammable than wood, and once ignited, treated material would burn very vigorously. The application of this treatment is therefore likely to be limited to certain specialized uses, and the following are a few of the instances where it is suggested the treatment might find application : electrical components and battery boxes, agricultural machinery components, machinery components in intermittent contact with water, pattern making, some wooden sports requisites, toys, brush backs, carving work, flooring, special bench tops and draining boards.

The results of the investigation have been reported in the press[1].

Preserving Boxes Used in Horticulture

About ten years ago it was not uncommon to receive requests from nurserymen and bulb growers about methods of treating the wooden boxes used for horticultural purposes—raising seedlings, tomato growing, forcing bulbs, etc. —to prevent them from decaying too rapidly. Some firms were in the habit of using several thousand or even several hundred thousand boxes annually, and the rate of depreciation of these boxes through decomposition of the wood was very high, and the expense of continual renewal considerable. The decay was said to begin mainly around the nails, which had become oxidized. It was reported that attempts to lengthen the life of the wood by immersing the boxes when new in hot creosote had proved unhelpful, mainly because the creosote had a harmful effect on the roots of plants, even though the treated boxes were kept out of doors to weather for several months before use. In order to obtain definite information it was considered desirable to carry out some tests, and in 1935 experiments were begun, in co-operation with the Ministry of Agriculture's Plant Pathology Laboratory, Harpenden, with the object of devising a practical means of overcoming this heavy wastage.

[1] Smith, D. N. Rosin-wax Impregnated Wood. *Wood* 1946, **11**(11), 321–322.

In July 1935, forty-five boxes were made at the Laboratory to regulation size and construction for use in forcing bulbs. Forty of the boxes were made from wood of Scots pine (*Pinus sylvestris* L.) and these were divided into eight groups, each of five boxes. One group was left untreated as a control, the others were treated as shown in Table II. In each group of five boxes, two were nailed with ordinary steel wire nails and three with galvanized ones. It was thought that by using a naturally durable timber, treatment might perhaps be unnecessary. Five boxes were therefore made of western red cedar (*Thuya plicata* Lamb.), which is light in weight, moderate in price, and has a high though somewhat uncertain natural durability ; only galvanized nails were used in these five boxes, as western red cedar is particularly corrosive to ordinary wire nails.

TABLE II. *Box Treatments*

Nos. of Boxes	Wood	Preservative	Method of Treatment
1–5	Scots Pine	Sodium fluoride (4% aqueous solution)	Open Tank Hot & Cold method
6–10	,, ,,	Zinc chloride (4% ,, ,,)	,, ,,
11–15	,, ,,	Proprietary A (2% ,, ,,)	,, ,,
16–20	,, ,,	,, B (4% ,, ,,)	,, ,,
21–25	,, ,,	Proprietary B (4% ,, ,,)	Dipped 15 secs.
26–30	,, ,,	,, C (solvent type)	,, ,,
31–35	,, ,,	,, D (,, ,,)	,, ,,
36–40	,, ,,	None (control)	None
41–45	Western Red Cedar	None	None

Proprietary A contained arsenic pentoxide, potassium bichromate, sodium fluoride and dinitrophenol.
,, B contained copper sulphate and potassium bichromate.
,, C was a 30 per cent chlorinated naphthalene solution.
,, D was a 25 per cent copper naphthenate solution.

It is difficult to quote accurate figures of cost based on these small-scale experiments, but the following notes will give a general idea. The cost (1946) of the water-borne preservatives varies from $\frac{1}{2}d.$ to $1\frac{1}{2}d.$ per box depending on the chemical used, and that of the solvent-type preservative is about $2d.$ per box. The cost of treatment must be added. Western red cedar is about 25 per cent dearer than Scots pine, which means an extra cost of about $1\frac{1}{2}d.$ per box. These figures are, of course, merely rough approximations.

When made and treated, all the boxes were sent to the Ministry of Agriculture's Plant Pathology Laboratory at Harpenden and were used for forcing bulbs, and subsequently for other crops, in order to discover whether treatment had any deleterious effect on growth, and to compare the effect of treatment on wood decay.

On September 18 and 19, 1935, the boxes were planted with different varieties of bulbs, and the subsequent cultural operations conformed, as nearly as possible, to commercial practice.

With the exception of the boxes treated with sodium fluoride, which caused slight lagging in growth, there were no appreciable adverse effects upon the flower crop. Details have been included in the published report*.

* Moore, W. C., and Bryan, J. Preserving Boxes used in Horticulture. *J. Roy. hort. Soc.*, 1946, **71**(3), 79–84.

After the flowers had been cut, the foliage was razed off and the boxes were stacked out of doors exposed to the weather till June, when they were emptied. The following month and at intervals during the next eight years some or all of the boxes that remained serviceable were planted, usually with seedlings. No adverse effect on growth was experienced with any crop in the treated or untreated boxes. When not in the glasshouse the empty boxes were invariably stacked out of doors. No particular care was taken of the boxes, but without doubt they received less drastic handling than would have been the case on commercial nurseries. The details of the different effects of treatment on durability are given in the report but a general idea of these effects may be gained from Table III.

TABLE III. *Durability of Boxes*

Preservatives	No. of Boxes Tested	No. of Boxes Serviceable after :—				
		5 Years	6 Years	8 Years	9 Years	10 Years
Scots pine						
None	5	3	0	–	–	–
Sodium fluoride	5	5	5	5	3	0
Zinc chloride	5	5	5	5	3	1
Proprietary A	5	5	5	5	5	3
,, B (open tank)	5	5	5	5	5	3
,, B (dipped) ...	5	5	5	5	4	0
,, C	5	5	5	5	5	2
,, D	5	5	5	5	5	5
Western red cedar						
None	5	5	5	5	5	5

On commercial nurseries many, if not most, of the boxes used for forcing bulbs or other purposes do not last more than a season or two, whereas the untreated boxes of Scots pine in our experiment lasted from four to six years. This may be accounted for by the fact that in commercial practice spruce, which is a less durable timber than Scots pine, may in some cases be used for boxes, and also the durability within the species may vary considerably according to its quality, amount of seasoning, and storage conditions prior to seasoning. Nevertheless, it is scarcely to be doubted that the expense of continual renewal could be greatly lessened merely by ensuring that the boxes purchased are really well made, and that they are handled with reasonable care.

Apart from this, however, the results of the experiments permit several definite conclusions to be drawn. Perhaps the most important and striking one is that boxes made from western red cedar and pinned with galvanized nails are vastly superior in lasting power to those made from Scots pine, and fully justify the relatively small additional cost ; for even after ten years under the conditions of the test they showed little or no sign of decay.

All the treatments carried out with the boxes made from Scots pine had a marked preservative effect and none of them had any noticeable deleterious effect on growth and flowering, though it would seem that sodium fluoride may have exerted a slight and transient toxic effect on narcissus and tulip plants.

The various treatments differed in effectiveness. One particularly interesting result was the poor performance of the water-borne preservatives applied by the open tank treatment compared with the solvent type preservatives applied as a dip treatment. This is not generally the case, although the special

conditions of exposure and the relative thickness of timber may account for it. The copper naphthenate solution (proprietary D) proved to be the most effective preservative. All five boxes treated with it were still sound and serviceable after ten years, but were then beginning to show signs of decay and were less well preserved than the western red cedar boxes. Sodium fluoride was least effective and there was little to choose between the other three preservatives employed.

There was earlier deterioration in boxes pinned with ordinary wire nails than in those pinned with galvanized nails, except in those treated with the copper naphthenate solution, where no such distinction could be detected.

Thus wherever possible, boxes made from western red cedar should be employed for horticultural purposes, and they need no special treatment. Where Scots pine is used, it is best to pin the boxes with galvanized nails and advisable to dip them, before use, for 15 seconds in a solvent type of preservative such as a 25 per cent copper naphthenate solution.

Fire Resistance Work

A survey of the inflammability and burning properties of about 100 different species of wood has been started, using an apparatus in which temperature conditions can be varied but at the same time closely controlled.

Experiments have shown that it is possible to impregnate certain kinds of cork sheet used for insulating purposes with fire-proofing solutions such as ammonium phosphate so that they are rendered both flame- and glow-proof.

IV. ADVISORY WORK

Advisory work throughout the Laboratory continues to make heavy demands on the time of scientific and technical staff. In so far as this indicates an appreciation of the value of research to industry it is to be welcomed, but any further increase will interfere unduly with the research programme. The problem thus created is not easy of solution for on the one hand, it is highly desirable in the national interest to afford the maximum possible assistance to manufacturers and on the other, conditions are changing so quickly that an expansion of the scope of researches is expedient. The following summary indicates the type of advisory work which has been called for during 1946.

Wood Structure. In the earlier part of the year, in spite of an increase in staff, it was just possible to keep pace with the demands for information, advice and instruction. In the latter part of the period there was a further marked increase entailing the identification of hundreds of samples of timber.

Physics. Some twenty research workers from various universities and other research institutions visited to discuss problems upon which the work of the Physics Section had some bearing.

Chemistry. One hundred and eight enquiries on chemical subjects were dealt with during the year.

Mycology. Three hundred and ninety-eight enquiries were dealt with by letter—an increase of about twenty-five per cent over the number for the previous year. The majority concerned prevention and treatment of decay in buildings, but an increasing number referred to decay in ships and boats.

Entomology. In addition to replies by leaflet, a total of five hundred and ninety-five enquiries was dealt with by correspondence during the year. This was an increase of twenty-five per cent over the number for 1945. In addition, nineteen inspections of insect-infested timber in buildings were made.

Seasoning and Wood Bending. The number of enquiries received during the year amounted to six hundred and thirty-eight. The Laboratory continued to act in an advisory capacity for the Board of Trade, Timber Control Department. As part of this work fifty-six visits have been made to firms engaged in kiln-drying timber and reports on all the visits have been submitted to the Department. Thirty-nine other firms have received visits on matters related to seasoning or wood bending.

Woodworking. Advisory work has constituted one of the major activities of the section. The subjects on which assistance has been sought have been concerned largely with sawmilling and manufacturing processes, special techniques and modification to equipment, but have also included problems of utilization, the handling and burning of wood waste, production of fibre boards and of wood flour, and charcoal manufacture.

Composite Wood. Two hundred and eighty enquiries were received during the year.

Wood Preservation. Advisory work was related to the preservation of timber for a wide variety of purposes. In addition, a number of enquiries regarding the modernization of commercial pressure-treating plants were received.

Timber Mechanics. Advisory work has made heavy demands on the staff and has shown no signs of diminishing.

External Relations. There was a steady flow of requests for advice throughout the year. The field covered was a wide one and, apart from the normal type of query, included enquiries on such diverse subjects as meter boards, pick handles, brushes, musical instruments, poultry houses and the harmful effects on workers of certain imported species.

F. Y. HENDERSON,
Director

REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1947

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Members of the Forest Products Research Board have the honour to submit our report for the year which ended on 31st December, 1947.

Keeping in view the general circumstances of the present time, we are well satisfied with the work which has been accomplished at the Laboratory during the year. Having regard to current national needs, emphasis has been laid on efforts to see that existing information is effectively known and applied, and on the investigation of immediate practical problems. We recognize the overriding importance of this direct service to industry at the present time, and are gratified to see from the Director's report that this is being unreservedly given ; but it is also clear to us that in the absence of research organisations or other facilities within the trade the volume of such service must further increase, and we cannot but feel apprehensive of the results which must follow in time from the continued pre-occupation of the Laboratory with short-term problems to the exclusion of the longer-range work which is the surest basis of advance. This aspect of policy will need close attention.

At the same time, we are glad to report the constantly improving relations with industry brought about through the more practical of the Laboratory's investigations. The large volume of advisory and short-term work not only disseminates the actual information required, but also plays an imponderable but very important part in the education of the timber-using industries, reinforced as it is by personal contacts made by all the specialist sections.

After two very successful years of collaboration in the Adhesive Makers' Panel between the producers of plywood adhesives and the Laboratory, the membership of the Panel has been increased to include representatives of the users of the adhesives. A second informal panel, the Radio Frequency Panel, has now been set up, on which the Laboratory, the Ministry of Supply, the National Physical Laboratory and manufacturers and users of radio frequency apparatus are represented. This Panel will enable industry's special requirements in the application of radio frequency heating to the seasoning of wood and the setting of adhesives to be considered in planning the Laboratory's research programme.

We have noted with satisfaction the establishment of a Forest Products Research Committee by the British Empire Forestry Conference when it met in London in June, 1947. The appointment of the Director of Forest Products Research as one of the Vice-chairmen of the Conference and as Chairman of the Forest Products Committee was appreciated as a mark of the esteem in which the Laboratory is held among the Empire's wood technologists. The meetings of the Committee, held at the Laboratory, afforded very valuable opportunities for discussions on research programmes, for the interchange of ideas between workers in similar fields of timber research and for the furthering of the cordial relations so essential between the research institutions in different parts of the Empire. The Forest Products Committee has now been

formally constituted as a continuing body with members accredited by the various governments.

During the year, no major change has taken place in the general programme of work. In view of the importance at the present time of the search for suitable substitutes for the timbers obtained from hard-currency sources, we have approved the high priority which is being given to investigations upon colonial timbers, particularly those of the West African colonies and of British Guiana. Even with these, however, the immediate systematic investigation of the properties of the large numbers of new species entering the home market in the post-war years has not been possible with existing staff and equipment, and for some timbers it has been necessary to furnish the prospective user with provisional limited information for his guidance in their use.

Shortage of staff and the claims of advisory work have also made necessary a review on the work on timber mechanics to ensure that the development of the new investigations into floor and roof construction in low-cost housing should no longer be delayed. We felt that maximum benefit with least disadvantage would be secured by suspending the work on fibreboard packaging. The great diversity of the merchandise to be packed brings into train so many factors requiring consideration and study as to involve an effort quite beyond the resources that the Laboratory could devote to it, and with the development of the interest of the Printing, Packaging and Allied Trades Research Association in the subject as an important part of its field, we have felt it proper that the study of it should be left to that Association. We have made the recommendation accordingly.

We have noted with satisfaction the completion of the equipment of the new Composite Wood Laboratory. Problems arising in the separate stages of plywood manufacture, and involving the individual machines, are already being worked upon, and as experience is gained with the plant as a whole, studies in production and yield can be undertaken, the results of which will put at the disposal of industry data of immediate use in the utilization of new timbers and the assessment of new processes.

The increasing importance of colonial timbers brings with it technological problems which must largely be dealt with at the source. Logs destined for import for conversion to sawn stock or plywood in this country should arrive free from deterioration by insect or fungus, and sawn stock imported should have been properly converted. We therefore welcome the programme of entomological work proceeding in collaboration with the colonial forest authorities for the control of insect damage in the country of origin, the investigations into the control of staining in logs, and the services and advice placed at the disposal of the colonies on matters of conversion and seasoning.

At the other end of the sequence of utilization, completion of the tropical testing house now pending will permit of studies of the behaviour under tropical conditions of both timber adhesives and assemblies. The results of such studies, supported by work carried on at the same time in the tropics themselves, will be of manifest importance both to the service departments and to the British exporter.

In our survey of the research plans of the various sections of the Laboratory, we have paid particular attention to those of the Woodworking Section, as we foresee a steadily increasing demand for information on this subject. We have recommended an expanded programme of theoretical studies and their application to practice, and also note with approval the proposed strengthening of this section by staff with industrial experience and the implementation of the policy of providing separate machines for research and production work.

Among the other activities of the Laboratory during the year we note these points of interest :—

DECAY IN SHIP AND BOAT TIMBERS

Instances of rot in ships and boats are being brought to the notice of the Laboratory with increasing frequency, and a recent survey of light naval craft has disclosed that serious deterioration of the plywood used in their construction can occur. The vast expansion of the shipbuilding programme during the war caused the adoption of changes in technique and materials, such as the extensive use of plywood and the use of timbers of lower quality, to meet the need for rapidly increasing production. No doubt these and other factors have contributed to this deterioration, which is now a matter of growing importance. A series of investigations on the predisposing conditions and the required remedial measures is in hand.

FUNGAL STAINING IN HARDWOODS

Sap-stain or blue-stain in softwood is a condition well known in the building industry, and the causes have been investigated so far that it is possible to prescribe effective preventive treatments. Similar stains in hardwoods have received much less attention, and a systematic study of the causes has been started. This is becoming increasingly necessary as the imports of new and susceptible light-coloured timbers from the tropics increase.

SPECIAL CHARCOALS

A process for producing special grades of charcoal required by the engraving section of the printing trade has been perfected, and a patent has been taken out. This type of charcoal has hitherto been obtainable only from America, and the Laboratory's process should, when it is developed commercially, render import unnecessary.

STRUCTURAL TESTS

We note with approval the investigations in progress upon economy in roofing and flooring timbers. The tests upon complete structures should lead to greater efficiency in the design of the buildings, and will undoubtedly yield results of great importance to architects and builders.

PREVENTION OF INSECT INFESTATION OF TIMBER

The extension of the work on preventing infestation by powder-post beetles of sawn timber in storage and the success which has already been achieved by the use of various formulations of D.D.T. and Gammexane have afforded satisfaction to the Board. When the results of the work are completed they should offer means of efficiently controlling powder-post beetles and possibly furniture beetles also. The co-operation with colonial forest departments in attempts to prevent infestation of newly felled timbers by pinhole borers has already been mentioned. The reports from the Gold Coast on tests already carried out are particularly encouraging and fully justify the further work now in progress.

CHEMICAL RESEARCH

The chemical work carried out during the year has yielded results worthy of note. In particular, the controlled destructive distillation of the resin of the British Guiana timber wallaba (*Eperua falcata*), which may account for as

much as 30 per cent of the weight of the timber, has yielded a valuable metallurgical coke and a phenolic substance which is highly fungicidal. The possibility is now opened of utilizing both resin and wood fibre on a commercial scale.

The analysis of other exotic timbers is proceeding.

E. J. SALISBURY,
Chairman.

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1947

INTRODUCTION

The year under review has been marked by a continued orientation of the work of the Laboratory towards investigations of the short-term type and away from those of a longer-term and more fundamental nature. This is reflected in the various sections' reports of progress which are increasingly becoming records of routine and advisory work enlivened only by the occasional more interesting short-term project and a small amount of fundamental research. The continuing shortage of soft-currency timbers with its associated problem of economy, the necessity of conserving hard currency, which brings with it the need to find substitute timbers, and the increasing tempo of the industrial effort—all these have conspired to lay a greater burden of advisory work and short-term problems upon our resources. This burden is the greater because of the position occupied by the Laboratory in relation to the industry it serves. Within the timber-consuming side of this industry there is a vast diversity of activities, often highly specialized and with circumscribed fields of interest. The Laboratory finds itself, therefore, not only the national research institute, but also the natural and indeed usually the sole authority to which industry can turn for advice, and fortunately, with its great range of specialist staff and equipment, it is well adapted to give this dual service. The same acute contemporary problems have demanded that the Laboratory should also concern itself increasingly with questions of availability and supply. This has been reflected in the visit of one of our senior officers to the West African colonies during the year, and in the further increasing liaison with other government bodies, notably the Timber Control and Raw Materials departments of the Board of Trade, the Colonial Office, and the Ministry of Works. There is as yet no evidence of a falling-off in the number of new species of timbers arriving in this country or of the work involved in meeting the requests received for information concerning them. An indication of this is given by the great increase in the number of enquiries, which, in some sections of the Laboratory, have exceeded those of last year by 50 per cent, and in one instance by as much as 70 per cent. However satisfactory this index may be of the part the Laboratory is playing in the national effort, it must yet be remembered that this service is met from the existing fund of data and experience, which is being added to by little more than such new data as accrue from current *ad hoc* work. The systematic accumulation of data is thus being progressively restricted, a matter for continued anxiety.

GENERAL

BUILDINGS AND EQUIPMENT

All the equipment of the new Composite Wood Laboratory has now been installed. A short description of the development of the work in Composite Wood and of the new plant appears on page 65. During the year construction has also been proceeding on the new intermediate kilns required to deal with the increase of seasoning of tropical timbers.

TOUR

The world shortage of timber together with international currency difficulties has greatly increased the importance of British West Africa as a source of timber for the United Kingdom. Before the war the timber exports of Nigeria and the Gold Coast consisted in the main of some half-a-dozen ' primary ' hardwoods. It is now generally realized, however, that the forest resources of these colonies can be fully developed only by exploiting the ' secondary ' timbers which constitute so large a proportion of the forest crop. Thus increased production is conditional on the United Kingdom (as the principal consumer) taking a greater variety of species than it has been accustomed to receive from this part of the world.

In order to obtain a clearer picture of the timber situation, it was decided to send an officer of the Laboratory to visit British West Africa. The main object of the tour was to gain first-hand knowledge of the forests and their timbers, to study local factors affecting production and to make recommendations on the research work and other steps necessary to ensure the utilization of these timbers in the most economical and effective way.

The tour proved to be of great value in guiding the Laboratory in its programme of timber investigations and utilization studies, and thanks are due to all those who assisted in the arrangements.

RADIO FREQUENCY PANEL

In furtherance of the policy of maintaining very close relations with industry, a Radio Frequency Panel has been set up with the object of discovering the needs of timber-using industries in which this method of heating is employed so that, in the planning of relevant research work, industrial problems may be taken into account. This Panel is composed of officers of the Department's staff from this Laboratory and from the National Physical Laboratory, together with representatives of the Ministry of Supply, the Radio Industry Council and industrial bodies. The constitution of the Panel is referred to in more detail elsewhere in this Report (page 71).

FIBREBOARD PACKAGING

Except for some routine and industrial testing, investigations in connexion with fibre-board packaging have been suspended during the year to release staff for work on problems associated with floor and roof construction in low-cost houses, which in existing circumstances was considered more urgent.

FIFTH BRITISH EMPIRE FORESTRY CONFERENCE

The fifth meeting of the Conference, held in London during June and July, was a significant occasion in the history of timber technology. For the first time those delegates having a direct interest in forest products research formed a special section of the Conference, with its own programme of discussions and tours. The Director of this Laboratory acted as Chairman to this section and as Vice-chairman of the main Conference, the Assistant Director attended as a delegate, and all the senior officers of the Laboratory took part in the specialist discussions. Most of these were held at Princes Risborough and included policy, technical matters, programmes of research and co-operation. Several joint sessions with the forestry delegates were held in London, and a comprehensive tour was arranged to enable the Forest Products delegates to gain an insight into many of the aspects of timber utilization in Great Britain.

At the final plenary session of the Conference, it was resolved that an independent Standing Committee on Forest Products Research should be

formed, and by the end of the year the Commonwealth governments had nominated their representatives. There is therefore now a permanent body whose function it is to co-ordinate all the Commonwealth and colonial work in timber technology, and to ensure close contact with forestry.

BRITISH CHEMISTS AND FOREST PRODUCTS

The origins of wood chemistry as a separate branch of applied science were almost contemporaneous with the foundation of the Chemical Society of London. In connexion with the centenary celebration of the Society, which took place this year, a special account of the influence of the discoveries of British Chemists on the industrial utilization of forest products was prepared for publication[1].

INSTRUCTION

No systematic courses of general instruction have been held during the year, but it has been possible to arrange instruction for periods of three or four days for groups of staff from industrial firms. The important work of training kiln operators continues, and seven courses with an aggregate attendance of 68 trainees have been held. Forestry students from the universities of Oxford, Cambridge, Aberdeen, St. Andrews and Bangor came for their yearly courses. The Oxford course is a post-graduate one, which includes students from the other forestry centres as well as overseas men at Oxford. One-day tours of instruction for parties of technical visitors have continued throughout the year.

DISSEMINATION OF RESULTS

In addition to the indirect publicity gained through the normal channels of specialist visits, lectures, and publications, direct propaganda has been carried out during the year in four ways—by visits to areas, by exhibitions, by trade ' brains trusts ' and through parties of visitors to the Laboratory.

Visits

The areas visited during the year included Shropshire, Buckinghamshire, Yorkshire, Cambridgeshire, Bedfordshire and Norfolk, as well as short visits to Edinburgh and Glasgow. These visits to the provincial and Scottish areas served to establish contact with industry at new points, to renew and improve relations with our existing friends in the timber-using trades, and to keep the Laboratory informed of industrial problems and developments.

Exhibitions

The most important exhibition of 1947 was that organized at the Royal Institute of British Architects for a fortnight from April 28th to May 10th. Exhibits of direct appeal to architects and builders were shown and some five thousand visitors attended, including eminent architects and many students, as well as the staff of several large firms. This exhibition secured wide publicity through the press for the Laboratory's work, and at the request of the organizers of the Building Exhibition, the exhibit, in a less technical form, was set up at Olympia. Here also the number of visitors and the ensuing publicity was most gratifying. The architectural exhibit was later sent to the School of Architecture, Leicester, for a fortnight.

Small exhibits were sent to the Royal Agricultural Show, Lincoln, and to the Bath and West Show.

[1] CAMPBELL, W. G. The Industrial Utilization of Forest Products. *Industr. Chem.*, 1947, **23**, 480–486.

An exhibit was also sent to the " Research in Housing Standards " exhibition arranged jointly by the Department of Scientific and Industrial Research and the Incorporated Association of Architects and Surveyors.

A comprehensive exhibit on " Insect Damage to Timber " was sent to the National Museum of Wales and, at the request of the Director of the Museum, has been retained there as a permanent exhibit.

' Brains Trusts '

In conjunction with representatives of the Timber Development Association, Ltd., meetings of the ' brains trust ' type were arranged in London, Manchester, Coventry, Leeds and Glasgow. The activities of the Laboratory were briefly described and members of the audience, which was largely drawn from industry, were then invited to submit questions concerning timber which were answered by the committee of officers of the Laboratory and of the Association. These meetings, which aroused much interested comment and were given wide publicity in the press, served to bring the work of the Laboratory to a wide circle of industrial people.

Visitors

The number of applications to visit has continued to rise and has made more difficult than ever the decision as to how many can be accepted without too much interruption of officers' work. The acquisition of two huts occupied till recently by the Ministry of Home Security has provided space for a lecture-room, a general exhibit on the Laboratory's work and a mycological exhibit. All those representatives of timber-using industries and professions who came to obtain information on specific problems have, however, been dealt with, as well as most of those who wished to visit with the wider purpose of discovering what fields of research were covered by the Laboratory, with a view to making more extensive use of its services. During the year, however, it has been found necessary to confine acceptance of applicants to those actively concerned with timber, and to refuse nearly all requests from parties of general visitors. Even so, it has been difficult to attend to visitors without unduly interfering with essential work.

ADVISORY WORK

The advisory work in all sections of the Laboratory continues to be very heavy and diverse.

The continued influx of new timbers during the greater part of the year has resulted in an unprecedented number of requests for information, and numerous enquiries have been received concerning possible substitutes for teak and other well-known timbers which are either no longer obtainable or which are in very short supply. It is gratifying to record that a considerable number of requests for information have come from members of the architectural profession and of the building industry.

The Laboratory has continued to act in an advisory capacity to the Timber Control Department of the Board of Trade on all matters related to the installation and operation of drying kilns. Numerous enquiries concerned with radio-frequency heating methods and with the plywood industry in the tropics have been received. The design and operation of modern pressure-creosoting plants were subjects of enquiries and there has been increased interest in preservatives other than creosote for pressure application. Requests for information and advice on matters connected with decay and fungal staining showed an increase of about thirty per cent on those of the previous year. Enquiries of a chemical nature have also been numerous. Wood-boring insects and their con-

trol accounted for a very large volume of internal work and in addition more than thirty inspections of insect-infested buildings were carried out.

In connexion with the rebuilding of the House of Commons the Laboratory was consulted by the architect, Sir Giles Gilbert Scott, O.M., R.A., and by the Ministry of Works, and at their request regular visits are being made to the firm of Messrs. Ashworth of Newport, Salop, to supervise the drying and check the condition of oak intended for the rebuilding of the House.

The Ministry of Works (Ancient Monuments Department) sought assistance in the selection and seasoning of oak for the repair of Westminster Hall. This has entailed visits of inspection to Whiligh, the source of the oak, and to Westminster Hall itself.

The Directorate of Furniture Production and manufacturers of utility furniture have made considerable use of the advisory service.

During the year, the Laboratory has been represented upon 25 main committees of the British Standards Institution, and upon the associated sub-committees.

The proportion of the Laboratory's time spent upon this advisory work and its associated investigations, and the effect upon long-term work, should not be underestimated. During the year some 3,700 enquiries were dealt with by letter or report. In addition, 1,158 requests for advisory leaflets were answered by post, 8,743 leaflets out of a total distribution through all channels of about 40,000 having been so despatched. If account be taken of all modes of conveying information—letter, report, visitor, visit or telephone—the number of technical enquiries demanding expenditure of staff time (apart from routine answer by leaflet) has been well over 10,000 during the year. It is of interest to note that, compared with the year 1945, the correspondence of the Laboratory has approximately doubled, and the evidence is that the proportion of technical to general correspondence has become greater. It may be noted that the body of expert scientific staff, excluding administration, directly concerned in dealing with this advisory work numbers 27.

PROGRAMME OF RESEARCH

WOOD STRUCTURE

The Laboratory's reference collection of timbers has been enlarged by the addition of nearly 800 specimens, including 282 species previously unrepresented. A notable acquisition is a collection of over 400 specimens of British Guiana timbers from the Colony's Forest Department. Of special scientific interest is a collection made by Mr. F. S. Walker, Colonial Forest Service, in the course of a recent survey of the forests of the British Solomon Islands Protectorate. This collection has not yet been examined and is not included in the figure mentioned above.

Apart from routine maintenance of the reference collection and technical records, activities during the year under review have been determined almost entirely by demands on the advisory services. Requests for identification or general information to guide importers and users have been concerned with over two hundred different timbers. Many of these are practically unknown outside their country of origin and continuous investigation has been required to provide the technical information that is necessary if they are to be used to the best advantage.

The large number of these "new" timbers in circulation has stimulated interest in practical methods of identification. In order to meet the demand,

a revision of the Laboratory's lens key to hardwoods, based on the perforated card system, has been put in hand.

Laboratory tests on a West African species of *Diospyros* indicate that it holds possibilities as a substitute for American persimmon and cornel in the manufacture of shuttles. The results of manufacturing and service trials are awaited. Investigations are also being made into the suitability of several other timbers.

Comparatively little work has been done on home-grown timbers. An investigation of the quality of samples of various timbers grown in the Isle of Man has been carried out for the Board of Agriculture and Forestry to provide guidance in selecting species for afforestation schemes on the island.

PHYSICS

Wood-water Relationships

Most of the work done on this subject during 1947 has aimed at the further development of the theory of swelling stresses in gels which was put forward in the Forest Products Research Special Report No. 6, published in 1945[1]. The report showed that it should be possible to determine the elastic constants of gels from measurements of their sorption and swelling under unidirectional mechanical restraints, and experiments which have now been made on wood, to test this prediction, have shown a fair agreement of the predicted moduli with those determined by orthodox methods.

A limitation of the original treatment given in the report, and one which was pointed out at the time, is that the gel is assumed to be perfectly elastic, implying that all strains produced by applied stresses are reversible, whereas in real gels this is seldom true, since residual strains are usually found to remain after the stresses have been removed. The occurrence of such residual strains was general in the experiments on restrained swelling mentioned above, and this made difficult the precise calculation of the elastic constants.

A theoretical study of the swelling stresses set up in plastic gels has therefore been undertaken and a preliminary discussion of the problem has been prepared[2]. This shows that swelling stresses cannot be calculated from the degree of swelling where plastic flow occurs, since the plastic component of the dimensional change does not bear a definite relation to the vapour pressure change induced by the stress. In certain circumstances the plastic flow can be allowed for and the swelling stress can then be calculated from the elastic component of the swelling by the former methods.

This discussion also proves the quantitative dependence of the sorption hysteresis on plastic flow and predicts that the volume swelling and shrinkage of the gel, when plotted against moisture content will show a hysteresis such that the volume on desorption is rather larger than that on adsorption at the same moisture content. The magnitude of the volume hysteresis depends on the bulk modulus and it is shown that for solid gels the bulk modulus is likely to be high enough to make the hysteresis negligible, whereas for porous gel the bulk modulus should be low enough to make the hysteresis measurable. This deduction is supported quantitatively by measurements of swelling and shrinkage made on synthetic cellulose fibres (solid) and on beech and spruce wood (porous).

Work on the routine determinations of the sorption isothermals of wood under various humidity cycles has continued satisfactorily but lack of staff

[1] BARKAS, W. W. The Sorption and Swelling of Cellulose under Natural and Imposed Restraints. *Proc. tech. Sect. Paper Makers' Assoc. Gt. Brit. Ireland*, 1947, **28**, Pt. 1, 1–22.

[2] BARKAS, W. W. A Discussion of the Swelling Stresses and Sorption Hysteresis of Plastic Gels. (F.P.R. Laboratory Report, October 1947).

has made it impossible to follow up the work begun on the theory of permeability of wood to gases.

Elastic and Plastic Properties of Timber

The study of the creep of wood and plywood under sustained shear load has been continued. Two methods are in use ; the first, developed at Madison, involves the bending of square plates, and the second involves the torsion of strips. The two methods have been compared, and the general picture presented by the creep behaviour proves to be the same by both methods. It is, however, difficult to obtain accurate estimates of the creep, because it is imposed on a relatively large instantaneous (" elastic ") deflection, and a small percentage error in the latter means a large error in the creep. For this reason, tests designed to measure the effect of humidity on the creep of $\frac{1}{2}$-inch Douglas fir plywood have failed to show any significant difference in the creep as measured at 30, 45, and 60 per cent relative humidity. At 75 per cent humidity, however, the creep is appreciably greater, and it is expected that when the measurements at 90 per cent humidity are completed, a further increase in creep will be shown. Efforts are being directed to improving accuracy and tests have been started on solid wood specimens to see if the errors are less for this material than for plywood. A study has also been made of the creep in torsion of a composite strip consisting of three $\frac{1}{32}$-inch brass strips fixed together with " Bostik " so as to form a single $\frac{3}{32}$-inch strip. The effect of the adhesive layers is considerable and although the material is obviously not directly comparable with plywood, the experiment shows that the effect of the glue layers on the creep of plywood may be appreciable.

Arising partly out of this work, some experiments have been made on the effect of long-continued loading on the Young's modulus of beech as measured by a flexural vibration method. It has been found that at 90 per cent relative humidity and under a load involving a maximum fibre stress of about 5,000 lb./sq. in., the modulus increases by 4–5 per cent over a period of a few days. The effect is approximately reversible, so that on unloading, the modulus drops and increases again when the load is re-applied. At 45 per cent relative humidity, there are signs of the same effect, but the changes in modulus are hardly greater than the experimental error. In view of the fact that negative results have previously been reported for the effect of continued loading on the modulus, this work will be carried on during 1948.

Some experiments are also in progress on the combined effect of temperature and moisture content on the three rigidity moduli of Sitka spruce. These measurements are being made in a manually-controlled model kiln, but it appears that greater accuracy might be obtained if some form of temperature and humidity control, automatic over a wide range of both, could be devised. Considerable attention has therefore been paid to this problem but so far a really satisfactory method has not been found. Control of humidity by salt solutions, by wood flour, and by direct injection of steam have been tried and discarded. At the moment a photo-electric method is being tried and shows some promising features, but trials have not gone far enough to say whether it will do all that is required.

SEASONING

Kiln-seasoning (Orthodox Methods)

The large kilns have been in fairly constant operation throughout the year. In them have been dried loads of 1-inch okwen (*Brachystegia* sp.), omu (*Entandrophragma candollei*), dahoma (ekhimi) (*Piptadenia africana*) and fotie (*Hannoa klaineana*).

These loads were obtained from the Timber Control for the specific purpose of determining the seasoning properties of Empire timbers.

Test results indicated that okwen would tolerate fairly severe drying conditions, but that omu would tolerate only mild conditions if distortion and collapse were to be avoided. Fotie could be dried readily with virtually no degrade, whereas collapse was a serious form of degrade in the drying of dahoma, even when this species was subjected to an unusually mild drying schedule. Loads of cricket bat willow clefts and 3-inch western red cedar were dried as a matter of interest to ourselves and a number of commercial firms.

The intermediate kilns have been used for the drying of loads of Empire and foreign timbers such as lapacho, baromalli, curupay and maho.

The small model kilns were used for small-scale drying of the above species and a number of others including mubura, haiariballi, danta and ekki.

Results indicated that curupay is refractory, as is also haiariballi, which is excessively prone to collapse. Baromalli and maho seasoned fairly readily, but tended to distort.

Small loads of briar blocks for pipes were satisfactorily seasoned and a small load of 3-inch pear is in process of drying.

So great has been the pressure of work on these intermediate and model kilns that it was found necessary to add to their number, and two intermediate type and one model are now in process of erection.

The old basement-type fan kiln is being converted into a side-fan cross-shaft type unit.

Seasoning (*Novel Methods*)

Laboratory tests to determine the possibilities of drying wood by means of temperature gradients from face to face of 1 inch thick panels have been undertaken, and the data obtained have been incorporated in a published report. This work links up with other work on the seasoning of wood in a high frequency field which has been in progress for some months.

Numerous tests have been made to investigate the possibilities of extracting the moisture in wood by causing it to boil in the high frequency field, and results have indicated that in green oak, for example, steam pressures, sufficient to rupture the fibres and induce serious surface and internal splitting, are generated rapidly.

Beech reacts rather more favourably, though, at times, degrade may be serious, and seldom are test results consistent. Difficulty also is experienced in drying to any definite and uniform moisture content without stressing the timber unduly.

The small kiln attached to the radio frequency set has been completed, and the method of drying by establishing a temperature gradient from centre to surface has received attention. Green beech has been dried satisfactorily by this method, though a much longer drying period is required than for boiling, and a normal conditioning treatment is required to complete the drying process. Work on these lines continues.

Specimens of beech, omu and Scots pine have been subjected to treatments in boiling acetone, similar to the treatments said to be effective in America. Results were disappointing, however, and the method employed showed little promise of proving successful, at least on the species chosen for test.

Tests on the seasoning of urea-treated wood continue but results to date are not encouraging.

Miscellaneous Work Related to Seasoning

Moisture meters, both of the resistance and capacity measuring type have been tested and calibrated, and a number of tests have been undertaken to determine whether such instruments, fitted with special electrodes, could be used for assessing the moisture content of thick building timbers.

Assistance has been given to the Timber Control in connexion with the re-grouping of species for the revised scale of charges for the kiln-drying of timber. Several commercial kiln installation schemes have been examined and commented upon at the request of Timber Control.

The supervision of the seasoning of oak for the re-building of the House of Commons has already been mentioned.

WOOD BENDING

Considerable attention has been given to the bending of plywood, and data relating to the limiting radius of curvature of Canadian and Finnish three-ply have been obtained. Various two- and three-ply assemblies have been made and tested. Certain two-ply constructions are promising from the point of view of bending, but lack stability when subjected to moisture changes in service.

Methods of producing bends of small radius, as required for the manufacture of radio cabinets, have been studied, and some new methods evolved.

A new method of producing laminated hoops has been developed which consists essentially of bending concentrically a number of prepared laminae. The method calls for accurate cutting to length of the laminae. Otherwise, it is comparatively simple and requires the minimum of equipment, and for that reason may be easily applied in industry.

Tests have been carried out on small consignments of *Diospyros crassiflora* and *Afzelia bipindensis*. The former was found to possess good bending properties, but those of the latter were very poor.

Although rock elm and white elm (*Ulmus thomasi* and *Ulmus americana* respectively) have been used extensively for boatwork, only a very limited amount of information relating to their bending properties appears to have been collected. Tests have therefore been carried out to obtain such data and to compare the bending properties of these species. In addition, the effect of density on the bending properties of white elm has been investigated. Both types of elm have been shown to possess excellent bending properties, only slightly inferior to those of Dutch elm (*Ulmus hollandica* var. *major*).

There did not appear to be any significant difference in the limiting radii of curvature of rock or white elm irrespective of density. The white elm, however, particularly the low-density material, was prone to distort during the actual bending operation, and also during the drying-out period. The findings would indicate, therefore, that the high-density rock elm is to be preferred. The results of this investigation have proved of interest to The Royal National Lifeboat Institution and other boat-builders.

The possibilities of softening and setting wood by means of radio frequency heating have been investigated, and it was found that $1\frac{1}{4}$-inch beech squares at a high moisture content could be rendered suitable for bending after heating for a period of two minutes. Such pieces, after bending, could for the most part be " set " satisfactorily after a treatment lasting ten minutes. The quick setting of bends by this method would seem to offer considerable advantages, in that forms and straps could be released in a much shorter time than is usual at present. Further work is needed on refractory species such as oak, etc., before the value of such treatments can fully be assessed.

A method for producing bends for spade handles by slotting and introducing glued inserts has been developed, and a number of frames and hoops have been made for the manufacture of herring barrels and for exhibition purposes.

TIMBER MECHANICS

Standard Tests of Strength

Standard strength tests have been made on Empire and foreign species new to this country.

Structural Tests of Timber

A temporary test unit has been improvised and a short series of tests started with the combined object of investigating certain principles of roof design and of obtaining the necessary experience in setting up large-scale structural tests to enable permanent equipment to be designed. The tests are being made on a 13-ft. length of roof of 22-ft. span. One roof has been tested and another is ready for test. The problems encountered have indicated the basic requirements of test equipment for this class of work, and the design of a permanent test unit, flexibly arranged to enable tests to be made of structures of all types, is going forward.

In connexion with a report for the Ministry of Works on the saving of timber which might be expected by the adoption of single-lap instead of plain tiles, practical nailing tests have been made with both types of tile to assess the point at which the " spring " of battens on increased spans is likely to prevent the driving of nails.

Two box beams with solid timber booms, one with hardboard webs and the other with plywood webs, have been tested for a firm of joinery manufacturers.

A revision of the section of the Housing Manual dealing with timber construction has been prepared for the Ministry of Works. Further assistance has been given with the revision of the Timber Economy Memorandum.

Recommendations have been made to the National Housebuilders Registration Council in connexion with the revision of specifications.

Strength of Joints

A review of methods of test employed by other investigators, preliminary to starting tests on " Bulldog " connectors, has led to the conclusion that inadequate attention has been devoted hitherto to strength in tension, probably on account of the difficulty of making tensile tests. Special equipment for such tests has therefore been designed and will be incorporated in a new 60,000-lb. capacity testing machine now on order. The importance of this approach has subsequently been confirmed by reports from Australia of service failures of connector joints in tension.

As Bulldog connectors are finding increasing use, some interim information is being provided by a brief series of tests within the capacity of existing testing equipment.

A few *ad hoc* maintained-loading tests of nailed and shear connector joints have also been made in connexion with the consideration of roofing schemes submitted for official approval.

To deal with an enquiry as to the feasibility of using western hemlock for tiling battens, nailing tests were carried out on this species and on Baltic redwood, using the following nails :—standard 12-gauge, 12-gauge blunted,

and 14-gauge. The 14-gauge were more effective than the 12-gauge blunted in reducing the splitting of the hemlock, but this species was still more prone to split than was the Baltic redwood with the 12-gauge nail.

Abrasion Tests on Wood Flooring

Standard abrasion tests have been made of the West African timber afzelia. Strength tests and abrasion tests have been carried out on two forms of composite softwood flooring of Swedish origin, which were submitted by an importer.

Work on the testing of timbers for resistance to abrasion when used as flooring has been resumed after curtailment during the war years. The results of the considerable volume of research which led to the development of the Laboratory's abrasion machine have now been augmented by much evidence regarding the behaviour of timbers in floors under all conditions of service. A comparison of such behaviour with that of the same timbers when subjected to the laboratory test has established that the surface wear and breakdown caused under service conditions can now be reproduced in the laboratory, thus confirming the efficiency and usefulness of the machine as a rapid means of determining the relative wearing qualities of timbers.

Hardwoods vary considerably in their ability to withstand abrasive action. Some wear comparatively smoothly without surface breakdown, whereas others show very great loss in smoothness of surface, particularly when used in floors subjected to heavy traffic. This loss may be accompanied by a slight " picking-up " of the fibres along the grain, as distinct from actual splintering ; or a surface cracking such as occurs, for example, round the medullary rays of quartered oak or along the zones of interlocked grain so common in many tropical timbers when quarter-sawn ; or a pronounced splintering and lifting of fibres. These different types of surface wear and breakdown and the more severe disintegration of surface occurring in flat-sawn material of some ring-porous hardwoods are shown in Figure 10 (facing page 74).

A detailed analysis of the behaviour of hardwoods under heavy industrial and other traffic has been carried out and a hypothesis advanced to explain the phenomenon of surface wear and breakdown. In the past, a high resistance to indentation, as measured by the standard hardness test, together with related high density, was taken as an index of good wearing qualities, but these new studies have shown that in general the resistance of the wood surface to actual breakdown and disintegration is not entirely related to density, but is appreciably affected by anatomical structure and in particular the arrangement, size and distribution of pores. Diffuse-porous hardwoods of coarse texture, for example, tend to break down by a collapse of the large pores, followed by rupturing of other wood tissue, and this is accentuated when the pores are arranged in oblique lines or when their numbers are great and results in the splintering form of surface breakdown. Hardwoods with small diffuse pores, on the other hand, suffer a local compression or consolidation of the structural elements as a whole, resulting either in comparatively smooth wear or in a slight " picking-up " of the surface fibres. The photo-micrographs in Figure 11 * illustrate the development of wear and breakdown in both these types of hardwood. In ring-porous hardwoods, the resistance to surface breakdown has been found to be largely dependent on the rate of growth. Slow-grown material appears to behave in a similar manner to hardwoods with diffuse pores and they break down on the surface accordingly, whereas in the fast-grown material a preponderance of summerwood offers resistance to surface breakdown, which offsets the weakness of the narrow springwood zone.

* Following page 74.

It was clear from these studies that the weakness in the structure of coarse-textured hardwoods is the large pores, with their tendency to collapse following compression. A reinforcement of these pores by filling them with a supporting medium must therefore tend to prevent their collapse and ensure comparatively smooth wear where otherwise splintering would occur. Confirmation of this hypothesis has been obtained from supplementary tests in which hardwoods impregnated with the rosin-wax mixture described in last year's Annual Report (see page 40) were subjected to the abrasion test. The results of these tests showed that such material with its pore cavities reinforced by the supporting medium resisted abrasive action and that the compression and collapse of the pores which lead ultimately to severe surface disintegration was largely prevented.

An important point concerns the selection of a timber for flooring. The Laboratory has for some time past maintained that, for maximum useful life as flooring, the conditions of traffic are of prime importance as a guide to the selection of suitable species. Accordingly a classification of traffic conditions into broad groups ranging from the very heavy traffic of an industrial nature to the light traffic in domestic buildings has been advocated. For greatest economy timbers should therefore be related to the traffic groups for which they are best suited. For example, the timbers most likely to give satisfactory service and maximum life under industrial traffic are the fine-textured hardwoods of high density, which wear comparatively smoothly without surface disintegration. The coarse-textured woods, on the other hand, are much less suited to heavy traffic of this nature and should be used under less exacting conditions. This approach to the question of abrasion is not merely of academic interest. Its practical significance lies in the fact that a quick method of assessing wearing qualities of hardwoods is now available. A knowledge of the structure of any hardwood will indicate its suitability for use as flooring and enable the type of failure under service conditions to be predicted with some accuracy, thus making possible the classification of new species into groups having different degrees of resistance to abrasive action.

A general paper on the results of these investigations has been accepted for publication[1]

Box Testing

Testing has continued for the London Offices of the Departments of Agriculture in Australia and New Zealand in connexion with the placing of contracts for fibreboard boxes for the export shipment of butter, and with the control of boxes supplied under contract.

Numerous tests have been carried out for the Ministry of Supply and for industry covering commodities ranging from perfumery goods to radio sets variously in wood and fibreboard containers.

COMPOSITE WOOD

Glues and Gluing

Glue shear-test pieces to a total of 9,380 have been pulled for the Composite Wood Section.

Pneumatic grips, designed to eliminate the personal factor present in existing glue shear-testing equipment, have been designed for a new 5,000 lb. capacity testing machine now on order. These grips will be used as the basis of standardized equipment, capable of adaptation to all types of testing machine,

[1] ARMSTRONG, F. H. Flooring Hardwoods : their Wear and Anatomical Structure. *Bull. For. Prod. Res.* No. 21. (London, H.M.S.O.)

which it is hoped to develop in order to enable glue shear tests for specification purposes to be carried out under uniform conditions.

The New Plywood Laboratory

The Laboratory's active interest in composite wood products (e.g. plywood, improved wood and glues) dates from 1935 when a survey of the industry made it apparent that there was a wide field of research which would yield much needed technical information. The installation of a small plant was authorized and a building 50 × 25 ft. in size (marked A on the inset plan of Figure 12) was erected to a house a 2 × 2-ft. peeling lathe, a glue mixer and a spreader, and a 2 × 1-ft. hot press, which, for work with " improved wood " would give platen pressures up to 4,000 lb. per sq. in.

The sudden death of the officer in charge delayed, for a time, the progress of the new section, but by mid-1939, work had begun on a preliminary programme which gave priority to the manufacture of " improved wood " and the investigations of new timbers for plywood, with the study of glues and gluing as a secondary subject. When war became imminent a revision of the programme was made to meet the immediate needs of the aircraft industry. It was clear that the most-needed investigation was into glues and gluing, since troubles with the relatively new synthetic resin adhesives in their application to assembly work were already wide-spread. Also, the possible shortage of Canadian birch for aircraft plywood added urgency to the examination of alternative species. Work on improved wood was, however, to continue because of the use of this material in airscrews.

During 1940 these three investigations continued. In collaboration with the colonial forest services, who supplied the logs, a number of African timbers were peeled, and their properties as plywood were compared with those of Canadian birch. Investigations into the manufacture of improved wood of the film-glued and impregnated types were carried on at the same time. With glues, the need for new specifications to test the properties of synthetic resin adhesives became apparent, for existing methods were adequate to assess neither water-resistance nor the efficacy of these resins in glue-lines of different thickness. The durability of these adhesives over long periods was unknown. and accelerated tests were developed and plans made to check their behaviour under exposure to natural conditions. About this time, also, collaborative work on acidity problems in glues was carried on with the Section of Chemistry.

The following year saw a great expansion of the glue investigations to meet particular service needs and manufacturing problems. The prospects of improving the durability of casein glue by the addition of toxic materials was studied. In all this work, the great need for background knowledge of natural durability and aging qualities to support the findings of the accelerated tests was manifest, and in what spare time was available, glued material was being prepared for weathering trials to supply this knowledge.

Work on improved woods continued, together with the essential concomitant studies of temperature-penetration and the time-temperature setting relationships of the bonding resins. Such physical properties as shrinkage, thermal expansion and creep under alternating humidities were examined. These investigations, however, were restricted more and more by the ever-increasing work on the adhesives, which included the problem of the gluing of improved wood itself.

Meanwhile, peeling trials of timber for plywood continued, and various physical properties of plywood itself were examined, such as shrinkage, moisture transfusion and the causes of cockle and distortion when it was glued to rigid frames—a trouble experienced in service aircraft which had to be parked in

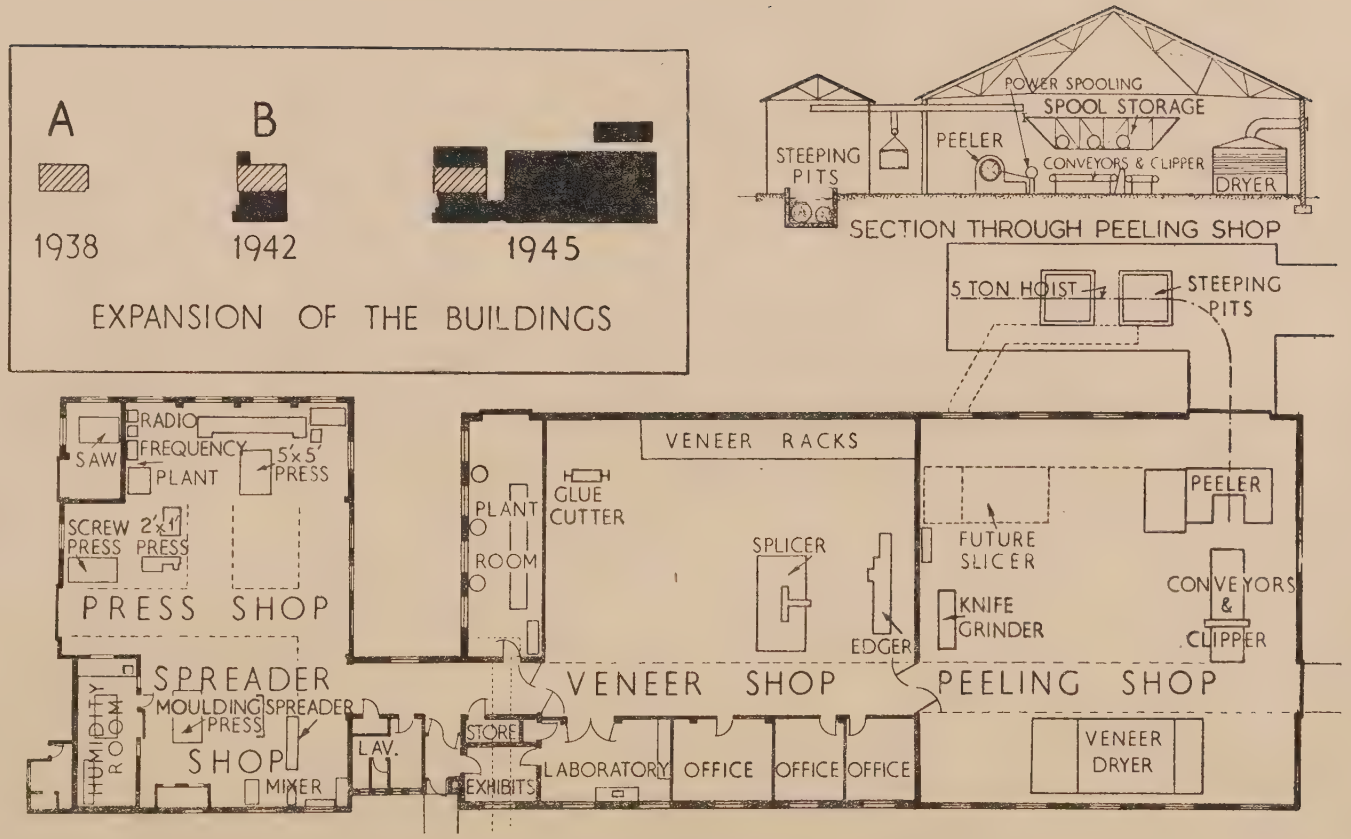


FIG. 12. LAYOUT OF THE COMPOSITE WOOD LABORATORY

open fields in all weathers. As an aid to this study, the wing of an ' Oxford ' aircraft was set up in the Laboratory's grounds for observation. Preliminary work during the summer months showed that insolation could induce surprisingly high temperatures on the wing surface, and plans were made to examine this effect more fully because of its probable effect on the glued joints.

These insolation experiments were made during the summer of 1942 and again on a much increased scale in 1943, by which time similar tests were under way in Australia, Canada, India and the United States. With the 1942 results as a basis, the Meteorological Office was asked to estimate the worst conditions of insolation in selected tropical countries in terms of daily temperatures and humidities, and from these figures was devised an accelerated cyclical test for the joints, which was later applied to a wide range of adhesives.

The year 1942 also saw the issue of new provisional standard specifications for synthetic-resin and casein glues. The testing technique then developed by the Laboratory is now the basis for British Standard specifications for all types of adhesives.

The continuing uncertainty of supplies of Canadian birch for plywood and airscrew manufacture led to a further search for substitute materials, and the possibility of combining veneer with resin-impregnated kraft paper was examined. For airscrews, a material was successfully developed (called Zebwood from its striped appearance) that would save 25 per cent of the veneer in a blade, but a form of plastic-reinforced plywood using low-density species such as poplar was not successful. As the supply of birch veneers was in fact maintained, neither of these substitutes came into use, but the work done on some subsidiary materials such as an improved form of plastic-faced plywood has since proved of value.

In this same year, the Ministry of Aircraft Production asked the Laboratory to investigate certain aspects of moulded plywood manufacture, and an extension (marked B on the inset of Figure 12) was erected to house the equipment. Unfortunately, there was much delay in obtaining the plant and work could not begin until the close of 1944.

An increase of staff in 1943 permitted a start to be made on the study of heating by radio frequency methods. Here again there was delay in obtaining plant, but in the interval work was continued in collaboration with a commercial firm, and a survey was made of the existing knowledge of this form of heating.

The post-war scarcity of plywood was foreseen by both industry and government departments, and the preliminary peeling trials of African species had aroused great interest. It had always been realized that the existing plant was too small and incomplete to give more than an indication of the worth of a timber, and plans were made to install what would be virtually a small factory for the complete manufacture of sheets up to five feet square in size. The final proposals were approved by the Department's Advisory Council in December, 1943.

Towards the end of 1944, the Ministry of Aircraft Production asked for a study of the uses of infra-red heating for accelerating the setting of synthetic resin glues. This work embodied both the fundamental and the practical aspects, and was continued during 1945.

In June 1944 an account was published of the weathering tests begun in 1940 upon plywood adhesives, and so great was the interest shown in the results that a wide extension of the work was planned. Towards the end of the year, it was possible to start making the large number of samples required for the ten-year investigation, and the actual exposure of some of the test

material began in February 1945. A view of the field site in 1947 is given in Figure 13.

After the war comprehensive long-term tests on the natural durability of glues was set up both for plywood adhesives and for assembly glues. The final results will not accrue for several years, but from year to year the experiments are yielding important interim data.

As a further means of studying the storage life, application, and performance of adhesives under tropical conditions, a three-roomed house was planned in 1945. An existing building was adapted to provide two compartments working on daily cycles of temperature and humidity corresponding with wet and dry regions of the tropics, as well as a work room with conditions capable of adjustment in extremes of dry and wet heat, together with simulated solar radiation. The installation of the equipment has been delayed, but it is hoped that this house will shortly be ready.

Early in 1945 was formed the Adhesive Makers' Panel, the first of the informal committees to maintain between industry and the Laboratory that excellent liaison which had developed during the war.

The radio-frequency plant had by now been delivered, and its application to glue-setting investigations has since been continuous. Much fundamental work was necessary and special apparatus for measuring power and other quantities has been devised and made. In these investigations liaison with industry is provided by the Radio Frequency Panel, an informal body first convened this year.

The setting-up of the Section's new plywood plant suffered from the inevitable post-war delays. Erection of the building began in June 1945 and was not completed until the end of 1946. Deliveries of machinery were slow, but the equipment was installed and most of it brought into operation by the end of the present year.

The plant is intended for experimental work on timber, machinery and manufacturing processes. It is of sufficient size to enable the value of a species to be assessed on a commercial scale, and will be much used for this purpose with hitherto unexploited Commonwealth and colonial timbers. Designed essentially for applied research, it is of paramount importance that both its methods of working and the results it produces should be readily capable of expression in a way that industry can interpret to its own needs. At this early stage, therefore, there will be formed the third of the informal industrial liaison committees, the Plywood Research Panel, to assist the Section in these aims. The Panel will at first be composed of technicians from the plywood industry but its membership will later be expanded to deal with any aspect of plywood production that may call for investigation.

The general layout is given in Figure 12 and Figures 14–19 show the various machines in operation.

Properties of Adhesives

The work of maintaining and extending the long-term durability tests on all types of adhesives has continued. On glues for plywood manufacture, the tests with home-grown beech, begun in February 1945, are now yielding cumulative results, and a report analysing the observations of the first complete year has been prepared. At this stage, it would be premature to give, in any detail, the indications of this experiment, but where the most severe weathering conditions are concerned, it is already certain that the phenolic resins are more durable than the urea resins.

Allied tests are now under way on 14 different adhesives, using lime and

gaboon for the plywood instead of beech. These timbers subject the adhesive to less harsh conditions of stress under changing weather conditions. At the request of industry, the question of possible variation of glue durability with other timber species is to receive attention.

For testing assembly glues, such as are used for joining together parts of structures, boats, aircraft and furniture, many types of test-unit and a wide range of exposure conditions must be employed. In 1946 a series of experiments on about 50 ply-clad frames was started (see page 33), and during the current year work on laminated beams has begun. These beams, of which there are 120, are 6 ft. long, 6 in. deep and 6 in., 4 in., or 2 in. wide, and they are bonded with a comprehensive range of glues. Some are exposed to the full weather, and others to outdoor conditions sheltered from rain and sun, whilst the remainder are stored indoors. They are examined and proof-loaded at monthly intervals. Both the ply-clad frames and the laminated beams are intended for long-term tests, and insufficient data are yet available upon which to publish results.

Aging tests continue on gap joints (i.e. those with a glue line 50-thousandths of an inch thick) made to the British Standard specification, and the number of glues under trial is steadily increasing. A progress report on such joints stored for four years shows that the decrease in strength over this period was about 25 per cent with urea resins and 10 per cent with the phenolics.

In collaboration with the Ministry of Supply, this work on the natural durability of adhesives is to be extended to tropical conditions, and plans are now being prepared. Also under consideration is the testing of adhesives for boat construction. To establish the need for this work, a survey of over thirty light naval craft has been carried out, facilities having been extended by the Director of Small Craft Disposals (Admiralty).

Amongst the smaller experiments has been one to determine the effects on the finished plywood of the moisture content of the wood at the time of gluing, and of subsequent changes. The influence of type of adhesive on the ' movement ' of plywood has been examined, and at the request of industry, information on the new polyvinyl acetate emulsions as wood adhesives has been compiled.

In March, the Adhesive Makers' Panel completed its second year, and the members took stock of its activities after consultation with their associations. It was unanimously agreed that informal panels of this type were highly effective as a means of liaison between the Laboratory and industry. The Chairman (Director of Forest Products Research) accepted the suggestion that adhesive-user interests, as well as those of the makers, should be included, and the Panel has been strengthened by representatives of the British Furniture Manufacturers Federated Associations, the Society of British Aircraft Constructors, and the Association of British Plywood Manufacturers. As examples of technical matters that are being dealt with by the Panel may be cited the descriptive classification of resin glues and methods of determining " pot life " of these adhesives, and the influence of additions of toxic material on the durability of animal and casein glues. At the Panel's request, and in collaboration with the Mathematics Department of the National Physical Laboratory, a statistical analysis of the failing loads of British Standards type glued joints is nearing completion.

From the Laboratory's point of view, the Adhesive Makers' Panel has been of very great help in the planning of research programmes to meet industrial needs. A sister panel, already referred to, has been set up recently to serve a similar purpose for the radio-frequency work.

Properties of Plywood

Experiments have been in progress for five years to determine the influence of veneer thickness on the surface-splitting of plywood exposed to the weather and to indoor conditions. They have shown that, even indoors, splitting is likely to occur if the thickness of the surface veneer greatly exceeds 0·06 in. Under outdoor conditions, the exposed veneer invariably splits, but if its thickness is of the order of 0·02 in. or 0·025 in., the defect is apparent only upon close examination. Some species are more prone to splitting than others, softwoods showing the most and some of the light hardwoods the least. The thickness of the cross-bands and other veneers in the core appears to be without influence on the splitting. The propensity to split is now examined as a routine for all species tested for plywood manufacture.

An allied matter that has troubled furniture manufacturers has been the cracking of ornamental veneers laid on a plywood base. Because of supply difficulties, the usual cross-banding has often been omitted and, to make matters worse, it may have been necessary to lay the veneer with the grain parallel with that of the supporting plywood. The unsoundness of this practice was realized by the trade, but its acceptance has been unavoidable. The Laboratory has been able to show that by control of moisture content and other conditions, such cracking can be minimized, although not entirely eliminated.

Grading of plywood for quality by the appearance of the face veneer is a trade custom of long standing, but with the introduction of so many new species a revision of standards must be made. A simple descriptive grading has been prepared that is applicable to all species and, although returns are not yet complete, industrial opinion is so far in good accord with that of the Laboratory. The scheme will be important in assessing the value of tropical timbers for plywood manufacture.

Work on the methods of making moulded or double curvature plywood has continued, but only a little time can be allocated to it. The number of industrial enquiries received during the year, however, shows the need for continuing the work.

Radio Frequency Heating for Setting Glues

The exploratory work referred to in the last Annual Report (see page 38) on the ' glueline ' method of applying radio frequency power to the setting of glued joints was completed early in the year and a progress report prepared.

Attention has been given to establishing a practical means of measuring radio frequency power, and to its application to glue-setting operations. The necessity for developing such apparatus had been brought out by the previous year's work and no instrument could be obtained to give the information required when operating at frequencies of the order of 10 megacycles per second. The method now used, based on a suggestion of the Radio Research Station, is to feed the load in a tuned circuit *via* a transformer whose primary and secondary currents are measured, for at resonance, the power delivered to the circuit is proportional to the product of these two currents. The apparatus was calibrated by substituting a continuous-flow water calorimeter for the load. The large tapped and screened transformer, and the calorimeter, flow-meter and special variable condensers were designed and constructed at the Laboratory.

Preliminary work on the application of radio-frequency heating to joints has shown that the rate of energy absorption in the glue-line may be measured progressively as the glue sets ; in a urea-formaldehyde glue joint subjected to

a constant voltage, the power developed in the glue quickly rises to a maximum, presumably while its conductivity is being raised by the heat, and then falls to a small value while the glue is setting and becoming dry. At the peak, the glue absorbed about 93 per cent of the power delivered to the type of joints tested. This was at a frequency of 5½ megacycles per second ; at higher frequencies a larger proportion enters the wood and is virtually wasted ; the proportion of power wasted in the wood is also greater when the whole heating cycle is considered.

The power data being obtained will be of value in selecting the optimum frequency for gluing work, in assessing the relative merits of different classes of adhesives from the radio frequency point of view, and in designing plant for specific applications.

The upper range of frequency of the present equipment is 45 megacycles per second, but a further generator has now been provided by the Ministry of Supply to raise this limit to 160 megacycles per second. Such high frequencies are of value where very high power concentrations are required, and where selective heating of the glue is to be avoided. During the coming year it is hoped to study the special problems which are presented.

Radio Frequency Panel

The field of research in radio frequency heating for wood is very wide, and though it may be desirable eventually to give attention to all practical aspects of it, priority will be accorded to existing or predictable applications by industrial users. It is also important, particularly in a new process, that the results of research be disseminated with the minimum of delay to all concerned. For both these reasons the closest co-operation between research organizations and industry is essential, and while cordial contact exists between the Laboratory and numerous individual firms, there is a need for augmenting this on a broad basis. To this end the Radio Frequency Panel has been set up, under the chairmanship of the Director. It is an informal body with functions similar to those of the Adhesive Makers' Panel, the membership including representatives of the wood-using and radio-frequency plant manufacturing industries, the Ministry of Supply and the National Physical Laboratory. In this way the needs of the user industries can be taken into consideration in formulating research programmes on the application to both glue-setting and timber seasoning, and the Laboratory will be kept abreast of technical developments in the electrical field ; similarly the results of the Laboratory's work will be rapidly brought to the attention of industry. The Panel held its first meeting on 12th November, 1947.

Low Voltage Heating for Setting Glues

The introduction of synthetic resin glues has resulted in the general use of hot press techniques in plywood manufacture and veneering. Conventional multi-daylight hot presses are, however, very costly, and any inexpensive method of modifying existing cold presses for hot press work is attractive to many firms. The use of semi-flexible electric heating pads of large area provides a solution and the method has already found application. This has a positive advantage over hot-plate methods for veneering, since rapid surface-heating followed by quick cooling after switching off can be easily and economically effected. The pads may be in the form of electric blankets operating at mains voltage, or may consist of bare metal sheets heated by a very large alternating current at low voltage derived from a transformer. The latter method has great advantages in safety, flexibility of application, and low replacement costs, and its study has been included in the Section's research programme ; diffi-

culties in delivery, however, make it necessary to postpone investigations until late in 1948.

The same process in the form of ' strip-heating ' is widely used for the setting of glues in laminated bends, and as such has been thoroughly studied in the Seasoning Section, but the project here referred to concerns the special problems which arise owing to the large increase in area of application. Increases in voltage above about 12 volts are not permissible for reasons of safety, so that very large currents of the order of thousands of amperes are involved, with concomitant mechanical and electrical problems. Difficulties are anticipated in obtaining uniform heating over large areas, and thermostatic control will be essential. An automatic control method based on the variations in element resistance with temperature has been devised and will first be tested on strip-heating applications by the Seasoning Section.

Other Plywood Investigations

Limited tests on the newly installed plywood machinery have been carried out.

An essential adjunct to the dryer is a rapid means of measuring the moisture in the emergent veneers. As a start the electrical resistance method is being tested, using an industrial model of moisture-in-timber meter, adapted for use on veneers, which are subjected to the application of upper and lower foot-actuated electrodes ; for these, electrically conductive rubber has shown promise. In contrast with solid timber, there appears to be no species correction for meter readings, and the thickness of the veneer has little effect. Owing, however, to the electrode configuration used, there is an overall correction to apply, which is about −2 to −3 at 15 per cent indicated moisture content. The method is therefore not precise but is useful for checking purposes.

Methods of edging and splicing veneers have been investigated thoroughly and several improvements to the machines have been made. Preliminary trials on a new type of " doctor roll " glue spreader showed that extensive alterations to the machine were required. These have been completed, and the machine, though as yet untested on long runs, shows promise of giving low and easily-controllable spreads of urea- and phenolic-resin glues.

Although until now the plant as a whole has not been available and none of the Empire timbers awaiting test could be tried for suitability as plywood species, a considerable amount of minor experimentation has been carried out both on the machines and on their methods of use. Steps have, for example, been taken to improve the performance of the glue mixer. This has involved making a study of the mechanics of mixing and the mixing properties of glues, followed by modifications of the machinery. As a start, casein glue has been studied and for this glue it has been shown that the problem of large-scale mixing centres round the rapid provision of a large free water surface, without splashing and consequent air entrainment ; and that stirring plays only a small part.

In 1946, the Board recommended that a veneer slicer be added to the Composite Wood plant. Negotiations for this machine have been in progress during the year, and delivery cannot be expected before 1950.

WOODWORKING

The Mathematics of Wood Cutting

Progress has been made in the mathematical analyses in sawing and machining operations. The relationships of the variables in the cutting

conditions to the instantaneous radius of curvature, clearance and cutting angles, thickness of chip and length of surface of separation, have been determined for rotary head planing machines for clockwise rotation of the cutterhead below and above the wood being cut. For circular saws, formulae have been derived relating tooth pitch, cutting speed, feed speed, depth of cut and height above saw centre to the depth of tooth penetration, number of teeth engaged and other factors which vary throughout the cut. The subject was discussed in some detail in an article "The Mechanics of Sawing—Circular Saws", published in the journal "Wood", June, 1947. Further experimental work in ripsawing by circular saw has been carried out on beech, wych elm, poplar and lime to determine the effect of variation in feed speed, tooth pitch, depth of cut and position of wood relative to the saw centre on the power consumption and the performance of the saw. These studies are part of an investigation to obtain information on the two aspects of the cutting action, i.e. the severance of the fibres and the detachment of the separated material as regards their individual effects on the resistance to cutting.

Woodworking Tests on Timbers Recently Imported

Routine tests have been carried out on the working qualities of the following species :—

Jequitiba (*Cariniana* sp.) from Brazil
Cedar, South American (*Cedrela* sp.) from Brazil
Okwen (*Brachystegia* sp.) from Nigeria
Mubura (*Parinari excelsum*) from Uganda
Curupay (*Piptadenia macrocarpa*) from the Argentine
Louro amarello (*Ocotea* sp.) from Brazil
Louro preto (*Ocotea* sp.) from Brazil
Espavel (*Anacardium excelsum*) from Costa Rica
Insignis pine (*Pinus insignis*) from Isle of Man

Revision of the Project for Woodworking Tests

The project for woodworking tests under standard conditions of cutting and determination of optimum conditions has been revised. A research programme on woodcutting and related matters was prepared for consideration of the Forest Products Research Board and the proposals for future studies and additional equipment were approved.

Miscellaneous Woodworking Investigations

Experiments with Grecian pruning saws were undertaken on behalf of the Colonial Office to determine the best tooth shape and spacing for pruning cypress in East Africa by native labour. The design of tools for cutting wood, paper and other materials bonded with synthetic resins, has received further attention. A survey of surplus sawmilling equipment in this country of suitable type for use in East and West Africa was undertaken for the Colonial Office.

Wood Waste as Fuel

Considerable interest is being maintained by enquirers concerning the most suitable methods and equipment for burning wood waste in its various forms. A leaflet "Wood Waste as a Fuel" has, therefore, been issued, which gives up-to-date information on the different classes of furnace and stove, and on the production of fuel-briquettes.

WOOD PRESERVATION

Testing of Wood Preservatives, Preservative Methods, and Durability of Treated and Untreated Timbers (Field Tests)

These tests have been in progress sufficiently long to show the value of wood preservatives when applied by impregnation methods. In comparison, surface treatments have only given very limited protection.

Tests are also still in progress to determine the natural durability of different species of timber in this country. It is now 15 years since these tests were started and an interim report on the results to date is being prepared.

Laboratory Testing of Wood Preservatives

Standard laboratory tests have been carried out on a number of proprietary wood preservatives at the request of the manufacturers concerned.

Experiments have been made to determine the effectiveness and rate of penetration of various volatile fungicides that could be used for the *in situ* treatment of timber beams infected with dry rot. Timber beams in buildings are sometimes found to be infected with a wood-rotting fungus at one end, but still sufficiently strong to carry the required load, and in such circumstances where the replacement of the beam may be an expensive matter, *in situ* treatment of the infected portion to prevent further development of the fungus may be worth while. In the preliminary experiments it was found that lateral penetration across the grain was slight. Of the antiseptics tested xylene gave the most promising results.

Transmission Poles

Experimental pressure treatments have been made in the Laboratory plant to provide data for formulating treating schedules to ensure satisfactory impregnation of a number of species now being used in this country for transmission poles.

Additional instances of premature failure of pressure-creosoted poles in service have been investigated during the year ; the cause of decay has been found to be unsatisfactory and inadequate creosoting, a direct consequence of creosoting insufficiently seasoned poles.

Mine Timbers

After inspections over a period of 17 years of the experimental mine timbers at two collieries, it was decided to bring the experiment on preservation to a close.

The need for the preservation of pit timber is recognized in all industrial countries and is indeed carried out to some extent in most of them. It must be realized, however, that the need for preservation does not arise in all mines, since the conditions in some are too dry for wood-destroying fungi to thrive. Moreover, with props used at the coal face economies are not effected by the use of preserved timber, because the mechanical life of such props is in any event short and indeed they may often be used only once. These two factors must, of course, be taken into account when the use of preserved timber is being considered for a particular mine.

The main uses for preserved timber are for props, bars and other supporting members in permanent or semi-permanent roadways, for ventilation screens and doors, underground construction in wood, rail sleepers, shaft timbers and linings and to a certain extent, though less than formerly, for tubs or trams.

Comparatively smooth wear

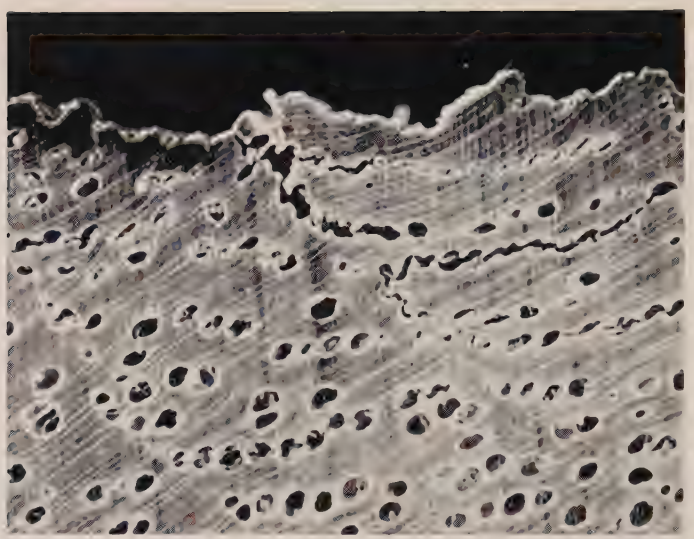
Surface roughening and slight lifting of fibres

Cracking round rays of quartered oak

Splintering and pronounced lifting of the fibres

Severe surface breakdown of flat-sawn material of some ring-porous hardwoods

FIG. 10. EXAMPLES OF TYPES OF SURFACE WEAR AND BREAKDOWN OF HARDWOOD FLOORING TIMBERS



Coarse-textured hardwood
Tasmanian oak (*Eucalyptus* sp.)

Fine-textured hardwood
Rock maple (*Acer saccharium*)

FIG. 11. PHOTO-MICROGRAPHS OF TRANSVERSE SECTIONS OF A COARSE- AND A FINE-TEXTURED HARDWOOD SHOWING DEVELOPMENT OF SURFACE WEAR AND BREAKDOWN (*Magnification* $\times$ 15)

FIG. 13. LONG-TERM DURABILITY TESTS ON ADHESIVES : PLYWOOD PANELS EXPOSED TO THE WEATHER

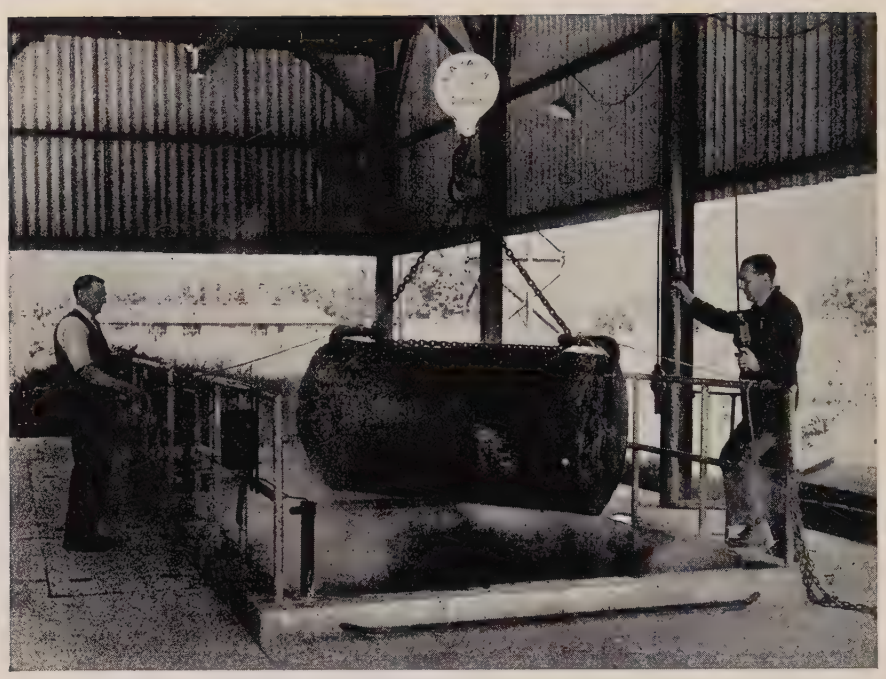


FIG. 14. PRE-TREATMENT OF PEELER BILLET

The first stage in the manufacture of plywood. The log has been cross-cut into billets of the required length, and one of these is being lifted from the pit after a steaming treatment that will make it easier to cut. Before the billet goes to the peeling lathe, bark and grit will be removed from the surface

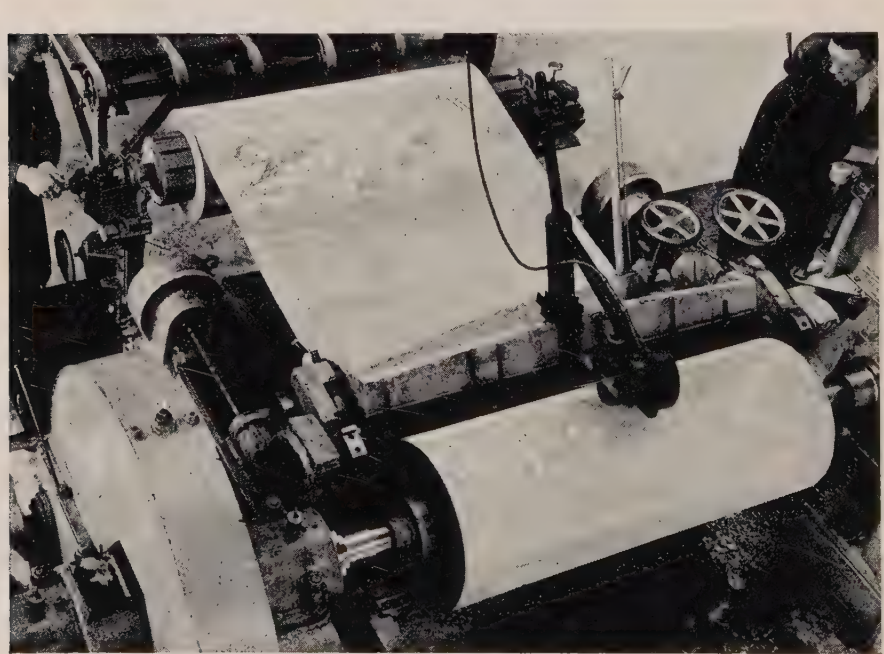


FIG. 15. PEELING VENEER FROM THE BILLET

The peeling operation viewed from above. In the foreground, the billet is seen mounted between spindles that are rotating. Behind and parallel with the billet is the massive carriage holding the knife, which is fed into the log and pares off a continuous sheet of veneer. This is wound on a spool located behind the lathe. Upon the top of the billet rests the gear that controls the rate of revolution so that veneer is produced at a constant speed

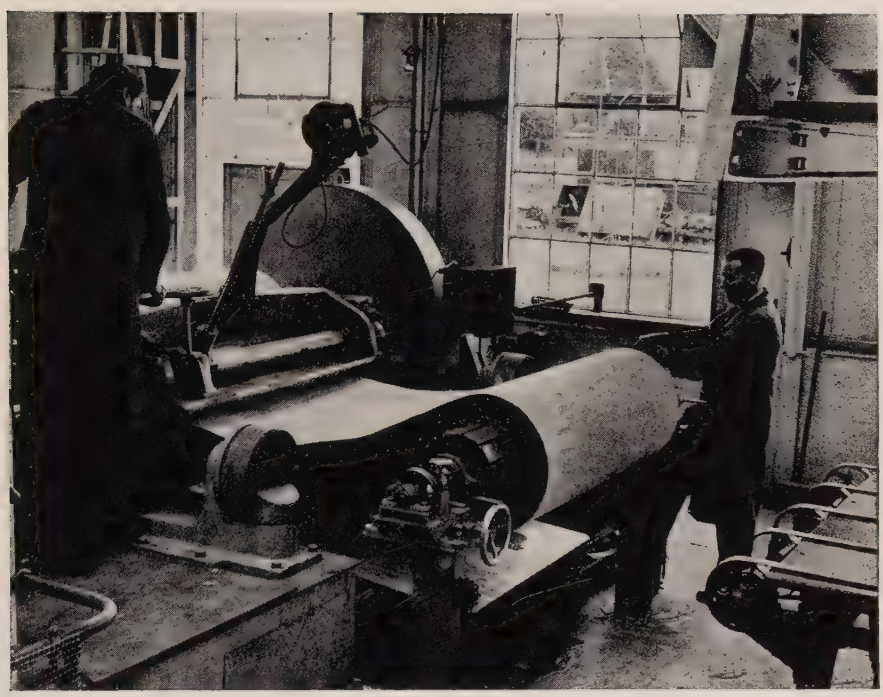


FIG. 16. SPOOLING THE VENEER

The delivery side of the peeler showing the knife carriage and the veneer being spooled. With billets of good quality, veneer has been cut at speeds up to 700 feet per minute. The spools can be driven by hand or by a motor mounted on the right-hand column. Power spooling is seen in Fig. 17

FIG. 17. VENEER CLIPPING

The veneer-handling gear. Full spools are stored on the overhead rails. The veneer from the spool on the extreme left is being unreeled by the action of the moving conveyor belts running over the table below. Veneer travels forward at a convenient speed, and defects are marked and cut out as it passes through the clipper. Sound material is picked off the right-hand conveyor, loaded on trucks, and taken to the dryer

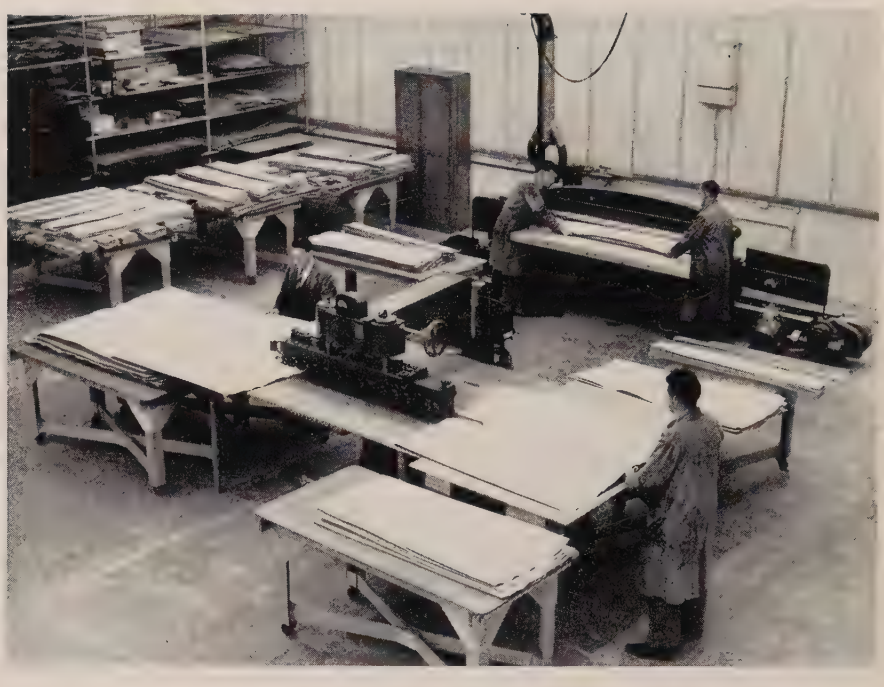


FIG. 18. EDGING AND SPLICING VENEER

In the background are narrow strips of good veneer obtained by the removal of defects from the continuous sheet. The machine on the right planes and spreads glue upon the edges of these veneers, which, in the splicer shown in the foreground, are then joined together to make wide sheets free from defects

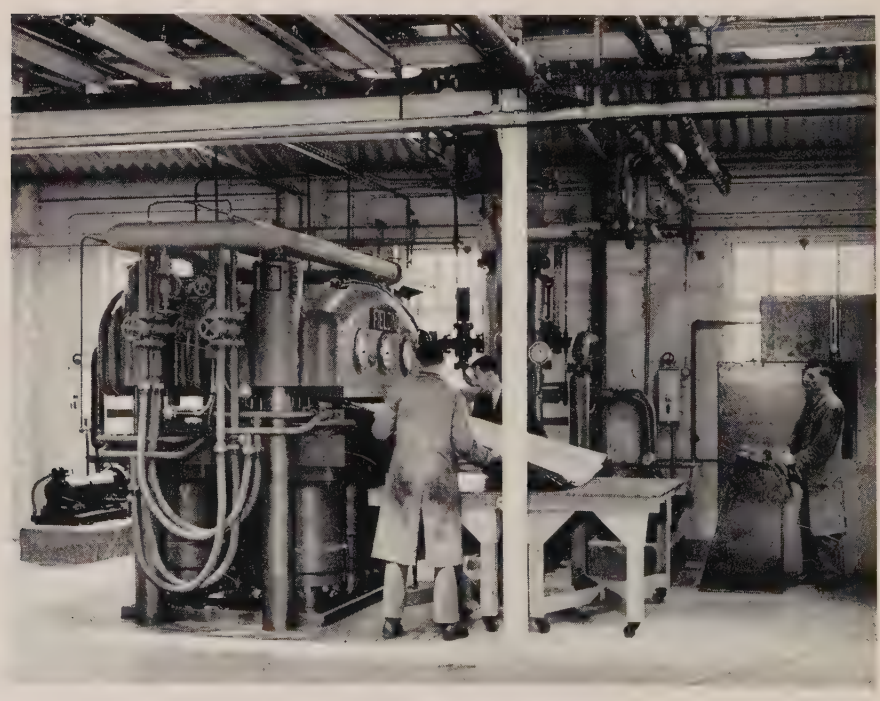


FIG. 19. LOADING VENEERS INTO PLYWOOD PRESS

In the manufacture of a three-ply board, a sheet of veneer is spread with glue on both sides and is laid between two others, the grains of which are parallel with each other but at right-angles to that of the middle piece. The assembly is loaded into the hydraulic press which applies the heat and pressure that bond the veneers together to form plywood

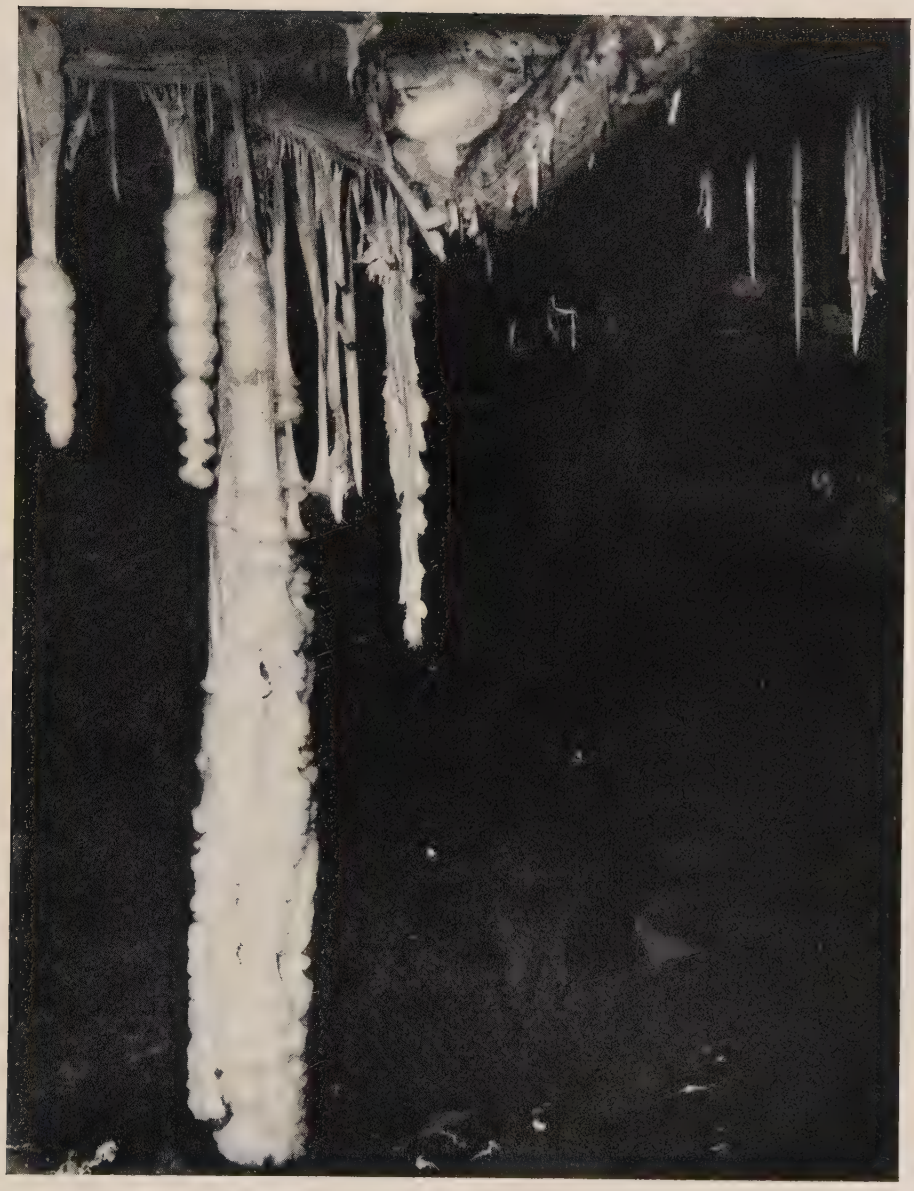


FIG. 20. TYPICAL FUNGAL GROWTH ON A PITPROP

FIG. 21. TREATED AND UNTREATED PITPROPS

Where conditions are favourable to decay, as frequently obtains, the life of props and other pit timber is very short. In some mines, for instance, the life of an untreated pitprop may often be as short as 6 months and where such conducive conditions are present, maintenance costs are very high, especially when the labour involved in replacing decayed timber is also taken into account. Thus if the life of timber in a mine could be increased five-fold, the amount of available pit-wood might be substantially increased.

Tests carried out by the Laboratory since 1930 on treated and untreated props have shown that this estimate of increased life is a conservative one, and that pit timber can be effectively preserved by a simple method of treatment with a number of readily available and inexpensive preservatives.

It is often overlooked that the early stages of decay are not always obvious ; the wood may appear sound, but the incipient decay causes a significant reduction in its strength. Frequently timber that has failed mechanically has done so because of loss in strength in this way. This is particularly true of wooden tubs which have to withstand a good deal of abuse and hard wear. Thus the use of treated mine timber also contributes to the safety of mining operations.

The object of these experiments was to demonstrate not only the economy and advantages of preservative treatment when applied to certain mine timbers, but also the ease with which such treatment can be applied. It was, accordingly, carried out at the pit-head using a simple form of open tank treating plant.

Preservative treatment, if widely adopted for mining timbers, could be carried out in a similar manner at individual collieries. Alternatively, pressure plants capable of dealing with much larger quantities of timber could be so located as to supply the needs of a number of collieries.

Figure 20 shows typical fungal growth on a pitprop. Figure 21 shows untreated and treated props in a mine and demonstrates the conspicuous absence of fungal growth on the treated prop.

Charcoal

A special type of charcoal commonly used in the preparation of photo-engraving plates has hitherto been obtained from foreign sources. In view of the urgent need for saving hard currency, attempts have been made to obtain supplies of this material in this country and the Laboratory was requested by the Board of Trade to examine the possibility of evolving a suitable technique for its production.

The problem was essentially to find a method of making blocks about 7 in. × 4 in. × 1¼ in. with particular properties. The usual methods employed for the combustion of wood are unsuitable for producing charcoal of specific dimensions of this order as the wood disintegrates into pieces of varying sizes during its conversion into charcoal. Moreover, the ordinary commercial product does not possess the required abrasive or polishing properties required of the charcoal used in the printing trade.

Earlier studies carried out at the Laboratory on the thermal decomposition of wood and the properties of the resultant charcoals had shown that the reaction is exothermic and also that the gases evolved during carbonization are given off at a varying rate. Decomposition of wood begins to become fairly rapid at temperatures about 200°C., gradually increasing up to about 270°C. Above this temperature decomposition is very fast and conversion to charcoal takes place within a short time.

It was evident from this work that splitting during carbonization could be avoided only if the gases were produced at a sufficiently low rate so that they

could freely escape from the interior of the wood. It followed from this that the main factors affecting the production of sound blocks of charcoal were the rate at which the wood was decomposed and the permeability of the wood itself to gases and vapours.

Experiments were therefore made in the first instance with permeable timbers such as lime and podo which were carbonized under controlled conditions of heating. The temperature was slowly raised until gases began to be given off, when the rate of heating was reduced until the evolution of gas was very small. Controlled heating of this kind was continued to a maximum of about 740–760°C., which was found to give a charcoal having the required properties.

It was found that although some timbers such as lime and podo gave the best results, suitable charcoal could in fact be obtained from a number of others, and samples submitted to the printing trade were reported as comparing very favourably with the normal, imported product.

The method of carbonizing developed for the production of this charcoal differs essentially from the normal procedure in maintaining rigid control over the rate of carbonization of the wood by regulating the temperature within close limits throughout the entire process and in using a higher final temperature. A provisional patent covering the production of charcoals having specific properties by this method has been taken out.

Fire Resistance Work

During the past year work on the fire resistance of wood has been confined mainly to the measurement of inflammability. The performance of about a hundred different species of timber has been investigated at several temperatures in the range 280°–600°C. The principal object of these tests was to find the fundamental causes underlying the very varied behaviour of wood at the time of ignition, and considerable progress has been made. It has been shown that temperature and density are two of the principal factors involved, and several others are now being investigated.

Experimental Pressure-creosoting Treatments

Experimental pressure-creosoting treatments have been made for the Central Argentine Railway to assess the practicability of creosoting white quebracho (*Aspidosperma* sp.) sleepers.

MYCOLOGY

Collection of Fungi

An important collection of dried specimens of wood-rotting fungi, identified by Dr. A. Pilat, has been purchased from the National Museum of Prague and incorporated in the herbarium.

Dr. W. P. K. Findlay was asked to act as secretary of a committee organizing an official specialist conference on Culture Collections of Micro-organisms and he acted as recorder of the conference which was held in August. The report of this conference has now been published : it recommends that an organization to be known as The British Commonwealth Collections of Micro-organisms should be established and that all information about the constituent collections of organisms should be available at the British Commonwealth Scientific Offices in London. The collection of timber fungi, which will continue to be maintained at the Forest Products Research Laboratory, will form an integral part of the British Collection of Cultures of Fungi for which the Imperial Mycological Institute will become responsible.

Additions have been made to the collection of cultures of sap-staining fungi and a new catalogue of the whole collection has been prepared. Many requests for cultures of fungi for testing and research purposes continue to be received.

A start has been made with the preparation of a perforated card key for the rapid identification of cultures of wood-rotting Basidiomycetes.

Physiology of Wood-destroying Fungi

The experiment on the longevity of wood-rotting fungi in wood kept at 25°C. in atmospheres of various relative humidities has been carried on, cultures being prepared from the test pieces at intervals of six months. Some species, notably *Lenzites* spp., are still alive after nearly four years in wood containing only about 12 per cent moisture. This experiment will be continued.

Work on metabolic products of wood fungi in co-operation with the Biochemistry Department of the London School of Hygiene and Tropical Medicine has continued. Interesting products obtained from *Polyporus benzoinus* are now being examined. It had been noticed that cultures of several *Endoconidiophora* species have a " peardrop " odour ; the ester responsible has been isolated and provisionally identified as isopropyl acetate.

Laboratory Tests on Decay Resistance of Wood and Other Materials

Standard laboratory tests on decay resistance of the following timbers have been carried out :—

African padauk, *Pterocarpus soyauxii*
essia, *Combretodendron africanum*
lapacho, *Tecoma* spp.
paletuvier, *Rhizophora* spp.
ekki, *Lophira alata* var. *procera*
afzelia, *Afzelia africana*
dahoma, *Piptadenia africana*
baromalli, *Catostemma commune*

An extensive test has been planned to determine the relative resistance to decay of the wood in different parts of a tree of ' Rhodesian teak ' (*Baikiaea plurijuga*). Samples taken at various heights in the tree and at varying distances from the pith have been obtained through the courtesy of the Conservator of Forests, Northern Rhodesia. Preliminary experiments have begun to determine which species of fungi are capable of causing appreciable losses in weight in this timber and would be most suitable for testing purposes.

At the Empire Forestry Conference a discussion was held on the value of laboratory tests of natural resistance to decay and it was decided that the various Dominion laboratories should co-operate in studying the technique of this test with a view to improving it and eventually to establishing a standard technique for the carrying out of the test so that results obtained from different laboratories would be directly comparable.

Further samples of composite building boards have been received from the Building Research Station and their resistance to fungi that cause dry rot has been tested.

Dry Rot in Buildings

One of the most difficult aspects of dry rot eradication is the sterilization of brick walls permeated with the strands of *Merulius lacrymans*. A method of effectively sealing the surface of the infected brickwork with an antiseptic coating would have considerable practical value. Experiments have been

carried out to determine whether " Hubbelite " magnesium oxychloride cement, which contains finely divided copper, could be used for this purpose. Blocks of wood heavily infected with *Merulius* were coated with a thin layer of Hubbelite cement and other control blocks were coated with ordinary Portland cement and sand (1 to 3). After several weeks in a damp chamber the fungus grew out through small cracks in the ordinary cement but no growth whatever appeared on those coated with Hubbelite. A report on these findings has been prepared and copies sent to the Building Research Station and the Chief Scientific Adviser of the Ministry of Works. Since finely divided copper is not readily obtainable at the present time, tests will be made to determine whether zinc oxychloride cement, which is more readily available, is equally effective. Eventually it is hoped to carry out practical tests on actual walls infected with *Merulius*.

Sap-stain of Wood

All the cultures of staining fungi in the collection have been examined, and microscopic preparations and drawings of the more important species have been made. As far as possible, cultures of the causal fungi are isolated from all the samples of stained wood that are received at the Laboratory. There is very little information available about the fungi that cause staining in hardwoods—a subject that is becoming increasingly important as the utilization of light-coloured tropical hardwood timbers is developed, and these fungi will be studied as material becomes available. Preliminary tests on the temperature relations of a number of staining fungi have been made.

A paper describing experiments on the effect of blue stain on the tensile strength of pine sapwood has been published"[1].

Rot of Timber in Ships and Boats

Numerous enquiries continue to be received about the treatment and prevention of decay in timber of wooden boats.

A fire launch, built only three or four years ago, was inspected and decay in the American elm timbers was found to be extensive, but not related to its position in the boat—it was, therefore, concluded that some of the timbers must have been infected before they were built into the boat. The occurrence of and factors responsible for decay of woodwork in boats merit further investigation. Instances of rot discovered in the plywood of light naval craft during the survey mentioned elsewhere in this report have been studied and described.

CHEMISTRY

Hydrolysed Wood as a Component of Welding Electrode Coating Compositions

During the 1939–45 war an investigation was carried out with a view to finding a home-produced substitute for the imported cotton flock normally used as an ingredient of the coating composition of certain types of welding electrode. The best substitute was found to be hydrolysed wood flour having a lignin content of the order of 36 to 40 per cent. Publication of the results was precluded under the Defence Regulations, but a complete patent specification[2] covering welding electrode coating compositions comprising hydrolysed wood in association with appropriate binding agents has now been published.

Commercial production of this special form of hydrolysed wood has continued since the war on a small scale.

[1] PETTIFOR, C. B., and FINDLAY, W. P. K. Effect of Sap-stain on the Tensile Strength of Corsican Pine Sapwood. *Forestry*, 1946, **20**, 57—61.

[2] HIRSCHLER, C. J., and CAMPBELL, W. G. Improvements in and relating to Welding Electrode Coating Compositions. *British Patent* No. 590,726, July 28, 1947.

Wood as a Causal Factor in the Corrosion of Metals

The Laboratory continues to receive enquiries from trade and other sources on the part played by wood in the corrosion of metals. When appropriate, advice is given conjointly by this Laboratory and the Corrosion Section of the Chemical Research Laboratory, Teddington. The general paper on this subject, which was presented to the Congrès International pour l'Exploitation et l'Utilisation Rationelles du Bois in Paris in 1946, has now been issued by the Ministry of Supply as a Scientific and Technical Memorandum[1].

Preparation of a Metallurgical Coke from the Resin of Wallaba Wood (Eperua *spp.*)

The wood of the wallaba tree of British Guiana contains a high proportion of an alcohol-soluble resin of a phenolic type. In an examination of several samples, the highest overall resin content was found to be 30·2 per cent and the lowest 9·7 per cent of the dry weight of the original wood. Several attempts to find a useful industrial outlet for this resin have not met with success, but it has now been found that by controlled destructive distillation, the resin can be converted into a metallurgical coke of high purity and good physical properties. The volatile products of the distillation include a complex mixture of phenols which has useful fungicidal properties, and a combustible gas of high calorific value. The results of this work have been accepted for publication[1][2].

Investigation has indicated so far that exploitation of wallaba wood solely to produce metallurgical coke from the resin would not be an economic proposition, but, as an adjunct to some other process designed to use the wood fibre, it might be of value. This work has been carried out on behalf of the Colonial Products Research Council.

The ε-Galactan of Larch Wood

A paper prepared in conjunction with Professor E. L. Hirst, F.R.S., and in which it is established that larch galactan is a mixture of a true galactan and a galacto araban, has been accepted for publication[3]. The type of structure present in the galactan is found to be the same as that indicated in a previous joint publication[4].

ENTOMOLOGY

Investigations on Lyctus *Powder-post Beetles*

(a) *Culture and Biology*

The technique developed for maintaining stocks of *Lyctus* beetles throughout the year has been of interest to enquirers in this country and to delegates to the Empire Forestry Conference in connexion with the adoption of a standard laboratory technique for breeding these insects. In order to amplify existing data on the duration of life-cycle of *Lyctus brunneus* under the conditions of culture (25°C. and 75 per cent relative humidity), some additional experimental work has been carried out with particular reference to the length of life of the beetles and to egg-laying and hatching.

[1] Campbell, W. G., and Packman, D. F. Chemical Factors Involved in the Utilization of Wood in Association with Metals. *Ministry of Supply. Sci.* and *tech. Memo.* No. 8/47, 1947.

[2] Farmer, R. H., and Campbell, W. G. Production of a Metallurgical Coke from the Resin of Wallaba Wood (*Eperua* spp.). *J. Soc. chem. Ind., Lond.*, 1948.

[3] Campbell, W. G., Hirst, E. L., and Jones, J. K. N. The ε-Galactan of Larch Wood, *J. chem. Soc.*, 1948.

[4] Hirst, E. L., Jones, J. K. N., and Campbell, W. G. The ε-Galactan of Larch Wood, *Nature*, 1941, **147**, 25.

(b) *Prevention of Infestation in Sawn Timber*

(i) *D.D.T. and Gammexane.* In continuation of work started in 1946, and because of the further and widespread trouble experienced through infestation by *Lyctus* in recently manufactured goods, chiefly of English oak, increased attention has been given during the year to methods of protecting stocks of hardwoods during seasoning and storage.

Tests, out of doors, on a semi-commercial scale with various formulations of D.D.T. and Gammexane, in progress since February 1946, have been continued and extended. The results, although not yet complete, indicate that most of the treatments have been effective, but it is noteworthy that untreated control material has not been infested to a common degree. Furthermore, the life-cycle of *Lyctus* in the controls has not been completed within a year. Re-exposure tests with timber treated early in 1946 and exposed to the rigorous climatic conditions that prevailed throughout that year suggest that a superficial application by spray of a 2 per cent solution of D.D.T. or of Gammexane in paraffin, or a 2 per cent D.D.T. water emulsion made up from a miscible oil concentrate, is sufficient to prevent infestation at least throughout the summer.

(ii) *Borax.* In view of the disadvantages in practice of hot water dipping treatments of green timber, as has been recommended in the past for the prevention of *Lyctus* attack, experiments have been initiated, out-of-doors and in the laboratory, to determine whether cold dipping or brush application with a 5 per cent solution of borax has any value in this connexion.

Laboratory Tests of Insecticides and Preservatives

In addition to the investigations out-of-doors, further work has been undertaken in the laboratory to determine the effect on wood-boring insects (*Lyctus brunneus*, and the common furniture and death-watch beetles) of contact for different periods with plywood surfaces treated with various formulations of D.D.T. and Gammexane. Examination of the data accumulated in the course of this work has not been completed but the results so far obtained may be summarized as follows :—

(a) *Oil Solutions*

Contact with surfaces treated with Gammexane appears to have a more rapid but less permanent effect on beetles than D.D.T. Samples of decayed oak sapwood, known from previous work to be suitable for infestation by the death-watch beetle, were treated with these preparations and, along with untreated controls, exposed to infestation by this insect. Beetles in contact with D.D.T.-treated material lived longer than those exposed to Gammexane. On neither type of sample were eggs laid, but egg-laying took place normally on the controls.

(b) *Dusts*

Beetles of the three species mentioned above, allowed to walk over surfaces treated with a 5 per cent D.D.T. dust took it up easily on the hairs of their bodies and soon became coated on ventral and dorsal surfaces. It was noticeable, however, that when in contact with treated surfaces for a short period, e.g. an hour, and then transferred to untreated wood, the insects were able to get rid of the dust and lived almost as long as untreated controls. The egg-laying capacity of such insects has been investigated.

(c) *Smokes*

Tests have been undertaken with D.D.T. smoke generators to determine their value for obtaining lethal deposits of D.D.T. on various types of surface in different positions in a room. Samples of plywood, rough timber and glass plates were exposed in a specially prepared room in which the smoke was liberated. Subsequently, wood-boring insects placed in contact with treated surfaces in the laboratory were found to be affected to varying degrees, but it was evident that the insecticidal deposit obtained was very slight on vertical surfaces, negligible on the underside but heaviest on the upperside of surfaces exposed in a horizontal position. Further experiments are required before the value of this mode of application of D.D.T. for the prevention of insect attack in structural or other timbers can be accurately assessed.

(d) *Polishes*

Progress has been made in the experiments referred to in the last report to determine the effect of treatment of infested woodwork with polishes containing 2 and 5 per cent D.D.T. or Gammexane. The results have confirmed earlier indications that emergence of insects through the treated surface is affected but not entirely prevented ; a high proportion of the insects is killed before the emergence hole has been completed. Work has also been undertaken to ascertain the effect of contact by *Lyctus* and common furniture beetles with surfaces treated with such polishes. The results so far obtained show that, as with the oil solutions, beetles are more rapidly affected by Gammexane-containing materials, but no information has yet been obtained on how long this effect persists.

Prevention of Insect Attack in Colonial Timbers

Information has been increasingly sought by firms with timber concessions in the colonies, particularly West Africa, for advice on the prevention and control of infestation by insects in logs and lumber for export. Furthermore, during the abnormally hot summer of 1947, trouble was experienced by importers in this country from pinhole borer beetles (Scolytidae and Platypodidae) emerging in large numbers from recently imported logs and attempting to infest, for the most part unsuccessfully, adjacent stocks of unseasoned hardwoods.

The general problem of prevention of such infestation of logs in the tropics has recently become of particular importance in relation to the exploitation of secondary timbers but also concerns species already known to be highly susceptible to attack. Satisfactory control measures are not at present known and their development and application are dependent on experimental work in the countries of origin. Efforts are being made by individual firms to start short-term investigations on their own particular problems, but as these are of general interest to all concerned in the closer utilization of colonial timbers, their solution could best be obtained by carefully planned research carried out by trained investigators working in close co-operation with forest departments and trade interests.

The general subject of the prevention of deterioration of logs and other forest products through infestation by insects and fungi was discussed at the Empire Forestry Conference, 1947[1] [2], at which a committee on forest pro-

[1] Fifth British Empire Forestry Conference. *Summary Report, Resolutions and Reports of Committees.* H.M. Stationery Office, 1947.

[2] FISHER, R. C. Some Timber Insect Problems in Utilization in the Tropics. *Paper contributed to the Fifth British Empire Forestry Conference,* 1947.

tection reported on the need for intensive studies, "*before* outbreaks actually occur, to determine the insects and fungi present in the forest" and, amongst other problems, to develop " the control measures necessary to protect round timber in the forest, not overlooking secondary species."

In this connexion, the Laboratory has continued to co-operate with colonial forest departments to determine from a series of preliminary experiments the value of D.D.T. and Gammexane for the prevention of pinhole borer damage in newly felled timber. Progress reports from the Gold Coast state that, although first results are encouraging, further work is required and is being carried out. Arrangements have been completed for similar investigations in the Malayan Union and British Honduras.

The Common Furniture Beetle, Anobium punctatum

Though staff was not available until the end of the emergence period of this insect in 1947 to enable a start to be made on the long-deferred programme of work on the biology and control of this common pest, it has been included in the series of tests with D.D.T. and Gammexane mentioned above. In addition, as part of investigations on the effect of different types of adhesive upon the susceptibility of plywood to infestation by this insect, preliminary work has been undertaken to explore the possibility of rearing the larvae in blocks prepared from wood flour and varying proportions of different glues of organic origin. This work is in its early stages but has an additional interest in relation to the need for developing improved technique for the testing of insecticides and wood preservatives.

The number of enquiries on the common furniture beetle dealt with during the year has been well above the average, and there is evidence to show the effect of storage of furniture and the closing of property during the war upon spread of infestation by this insect. A brief survey of infested property in parts of Scotland has shown that this insect is responsible for extensive damage in that country.

The Death-watch Beetle, Xestobium rufovillosum

At the request of the Ancient Monuments Division, Ministry of Works, an examination of the roofing timbers in Westminster Hall was carried out during the year to determine the condition of the timbers with reference to damage by the death-watch beetle. A report has been submitted to the Ministry of Works and the Laboratory's recommendations for limited insecticide treatments have been accepted and are shortly to be carried out.

The twelfth annual inspection of the timbers in H.M.S. Victory, infested by the death-watch beetle, was carried out in June when control measures were reviewed and discussed with the authorities at Portsmouth. An experimental treatment with D.D.T. dust has been applied during the year.

The House Longhorn Beetle, Hylotrupes bajulus

During the year a recurrence of instances of damage by this important pest of softwood structural timbers was noted in localized areas in Surrey. The buildings affected have been inspected and work is being continued on the collection of data on the occurrence of this insect with a view to determining the factors affecting its distribution and to ensure its effective control.

F. Y. HENDERSON,
Director

APPENDIX I

RETIREMENTS FROM THE FOREST PRODUCTS RESEARCH BOARD

1939 Sir James Irvine, C.B.E., F.R.S.
Air Ministry : W. S. Farren, M.B.E.
Colonial Office : G. L. M. Clauson, C.M.G., O.B.E.

1940 Professor R. S. Troup, F.R.S. (Deceased).

1941 Sir John Stirling-Maxwell.
E. P. Tetsall.
Ministry of Supply : Brigadier A. P. Sayer, D.S.O.
Ministry of Works : T. P. Fish.

1942 W. H. Mills, Sc.D., F.R.S.

1943 Admiralty : W. R. Kent.
Ministry of Works : Guthlac Wilson, S.M., B.Sc., M.I.C.E., M.Am.Soc., C.E.

1944 Colonial Office : V. A. Boyce, O.B.E. (Appointed 1939).

1945 Conrad Gribble.
Lord Bolton (Appointed 1941).
Professor H. G. Champion, M.A. (Appointed 1940).
W. A. Robertson, C.M.G., F.R.G.S.

1946 G. M. B. Dobson, D.Sc.
W. O. Woodward (Appointed 1941).
Ministry of Supply : Brigadier F. E. Fowle (Appointed 1941).
Ministry of Supply : W. D. Douglas, D.Sc., F.R.C.Sc.I. (Appointed 1939).
Admiralty : F. W. Perkins (Appointed 1943).
Ministry of Works : P. O. Reece, A.M.I.C.E., M.I.Struct.E., A.M.Inst.Mun.E. (Appointed 1944).

1947 Professor V. H. Blackman, Sc.D., F.R.S. (Appointed 1939).
Professor B. R. Ward, F.R.I.B.A. (Appointed 1939).
Colonial Office : W. B. L. Monson (Appointed 1944).

APPENDIX II

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

31*st December*, 1947

Director of Forest Products Research : F. Y. Henderson, D.Sc., D.I.C.

ADMINISTRATION

Assistant Director : S. T. C. Stillwell, B.Sc.
Senior Principal Scientific Officers : J. Bryan, M.Eng., A.M.Inst.C.E. ; K. St.G. Cartwright, M.A., D.I.C., F.L.S.
Higher Executive Officer : L. Forbes.
Executive Officer : Miss D. Lacey.
Senior Experimental Officer : W. R. Hutchins.
Temporary Senior Photographer : W. J. Baldwin.
Assistant II : E. A. Steel.

SECTION OF WOOD STRUCTURE

Principal Scientific Officer : B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge).
Senior Scientific Officer : E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Experimental Officer : G. L. Franklin.
Assistant Experimental Officer : Miss L. F. P. Wood, B.Sc.

SECTION OF PHYSICS

Principal Scientific Officer : W W. Barkas, D.Sc. (Officer in Charge).
Senior Scientific Officer : R. F. S. Hearmon, A.Inst.P.
Experimental Officer : J. McC. Paton.
Assistant Experimental Officer : J. N. Burcham.

SECTION OF SEASONING

Principal Scientific Officer : W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officer : D. D. Johnston.
Experimental Officers : A. R. Dean ; R. E. Hodge, A.I Mech.E. ; G. H. Pratt ; N. Turner.
Temporary Assistant III : Miss E. L. Bearn.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer : J Latham, B.Sc. (Officer in Charge).
Senior Scientific Officer : F. H. Armstrong, M.Sc., A.M.I.Mech.E.
Senior Experimental Officers : A. J. Foord ; Miss C. B. Pettifor, B.Sc.
Temporary Assistant Experimental Officer : G. R. Brock.
Temporary Appointment : J. G. Sunley, B.Sc.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer : N. A. Richardson, B.Sc., A.R.I.C. (Officer in Charge).
Senior Experimental Officer : D. N. Smith.
Experimental Officer : L. W. Redding.
Assistant Experimental Officers : Miss E. Lee ; D. F. Purslow.

SECTION OF CHEMISTRY

Principal Scientific Officer : W.G. Campbell, B.Sc., M.S., A.R.I.C. (Officer in Charge).
Senior Scientific Officer : R. H. Farmer, B.A., B.Sc., D.Sc. Tech., F.R.I.C.
Experimental Officer : D. F. Packman.

SECTION OF MYCOLOGY

Senior Principal Scientific Officer : K. St.G. Cartwright, M.A., D.I.C., F.L.S. (Officer in Charge).
Principal Scientific Officer : W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A.
Scientific Officer : J. G. Savory, B.Sc.
Experimental Officer : E. C. Badcock.

SECTION OF ENTOMOLOGY

Principal Scientific Officer : R. C. Fisher, B.Sc., Ph.D. (Officer in Charge).
Senior Scientific Officer : J. D. Bletchly, B.A., B.Sc.
Experimental Officer : E. C. Harris.
Assistant Experimental Officer : Miss J. E. Green, B.Sc.
Temporary Assistant Experimental Officer : Miss N. E. Kent, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer : P. Harris, B.Sc., A.M.I.Mech.E. (Officer in Charge)
Experimental Officer : H. J. Endersby.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officers : H. A. Cox, M.A., Dip.For., Dip.Tim Tech. (special duty) ; C. W. Scott, O.B.E., D.F.C., B.Sc., Dip.For. (Officer in Charge).
Senior Scientific Officer : E. H. Nevard, B.Sc., D.K.C.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer : R. A. G. Knight, B.Sc.(Eng.), A.M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer : P. M. C. Lacey, B.Sc., D.I.C.
Temporary Scientific Officer : J. F. S. Carruthers, B.Sc.
Experimental Officers : L. S. Doman ; R. J. Newall.
Assistant Experimental Officer : H. A. Howe.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer : C. J. N. McCracken, B.A., Dip.For., (Officer in Charge).
Experimental Officer : C. L. Stocker, B.A., Dip.For.
Temporary Assistant Experimental Officer : Miss J. M. Leisegang, B.Sc.

APPENDIX III

LIST OF PUBLICATIONS ISSUED DURING THE YEARS 1939–1947

A. Stationery Office Publications

		Price
Report of the Forest Products Research Board for the year 1938 (Out of print)		
Bulletins :		
No. 1.	Dry Rot in Wood, by K. St.G. Cartwright, M.A.(Oxon.) and W. P. K. Findlay, B.Sc. (Fourth edition, 1944)	1*s.* 0*d.*
No. 14.	Moisture Content Determination, by R. A. G. Knight, B.Sc.(Eng.), A.M.I.Mech.E. (Second edition, 1939) (Out of print)	
No. 19.	Beetles Injurious to Timber and Furniture. (1943)	1*s.* 6*d.*
No. 20.	Requirements and Properties of Adhesives for Wood, by R. A. G. Knight, B.Sc.(Eng.), A.M.I.Mech.E. (1946)	6*d.*
Records :		
No. 9.	Methods of Applying Wood Preservatives : Part I. Non-pressure Methods, by J. Bryan. (Revised edition, 1946) ..	6*d.*
No. 17.	Wood Preservatives, by N. A. Richardson. (Revised edition, 1946)	6*d.*
No. 28.	Strength Tests on Structural Timbers. Part 4. The Development of a Minimum Structural Grade for Redwood (*Pinus sylvestris*), by C. J. Chaplin, M.Sc., M.E.I.C., M.I.Mech.E., and E. H. Nevard, B.Sc. (1939) (Out of print)	
No. 29.	The Manufacture of Charcoal in Portable Kilns, by G. H. Donald, B.A.(For.). (1939) (Out of print)	
	Supplement No. 1. (1939) (Out of print)	
Special Reports :		
No. 5.	Recent Work on the Growth, Structure and Properties of Wood, by S H. Clarke, M.Sc. (1939) (Out of print)	
No. 6.	Swelling Stresses in Gels, by W. W. Barkas, D.Sc. (1945) ..	9*d.*
Miscellaneous :		
	A Handbook of Home-grown Timbers. (Second edition, 1939, out of print) (War emergency edition, 1941, reprinted 1945)	1*s.* 6*d.*
	A Handbook of Empire Timbers. Edited by H. A. Cox, M.A. (1939, out of print) (Revised edition 1945)	3*s.* 0*d.*
	Recognition of Decay and Insect Damage in Timbers for Aircraft and other Purposes. (1943) (Out of print)	
	A Handbook of Woodcutting, by P. Harris, B.Sc.(Eng.), A.M.I.Mech.E. (1946)	9*d.*
	Decay of Timber and its Prevention, by K. St.G. Cartwright, M.A.(Oxon.) and W. P. K. Findlay, D.Sc.(Lond.) (1946)	12*s.* 6*d.*

B. Other Publications

Leaflets* :

No. 4. The Death-watch Beetle. (Revised edition, 1943)

No. 6. Dry Rot in Buildings. Recognition, Prevention and Cure. (Revised editions, 1942, 1945, 1947)
Supplement to No. 6—War Conditions and Dry Rot. (1943) (Out of print)
Supplement No. 2 to Leaflet No. 6. (1944) (Out of print)

No. 7. Moisture Content Determination by the Oven-drying Method. (Revised edition, 1943)

No. 8. The Common Furniture Beetle. (Revised editions, 1941, 1943)

No. 9. The Moisture Content of Timber in Use. (Revised edition, 1945)

No. 10. The Overhead Internal Fan Kiln (Double Stack Pattern). (Revised editions, 1941, 1943)

No. 11. The Hot and Cold Open Tank Process of Impregnating Timber. (Revised edition, 1945)

No. 12. Sap-stain in Timber. Its Cause, Recognition and Prevention. (Revised edition, 1942)

No. 15. Summer Felling. (1940)

No. 16. The Steaming and Seasoning of English Beech. (1940)

No 17. Pinhole or Powder-post Damage ? How to distinguish Two Common Types of Insect Attack in Hardwoods. (1941)

No 18. A Cross-shaft Overhead Fan Kiln. (1941) (Revised edition, 1943)

No. 19. Grading Softwoods for Strength. Stress-grades for Beams. (1941)

No. 20. The Treatment of Timber in a Drying-kiln. (1941)

No. 21. The Air-seasoning of Converted Green Timber. (1942)

No. 22. Economy in Timber. Maximum Safe Spans for Joists and Rafters of Graded Timber. (1942)

No. 23. Circular Saws. (1942)

No. 24. Further Notes on the Manufacture of Charcoal in Portable Kilns. (1942)

No. 25. Uses for Sawdust and Shavings. (1942)

No. 26. Furnaces and Stoves for Burning Sawdust. (1942)

No. 27. Foreign Timbers—1. Notes on Jacareuba (*Calophyllum brasiliense*) and Cedro (*Cedrela* sp.). (1943)

No. 28. Kiln-drying in War-time : Quantity or Quality ? (1943)

No. 29. Foreign Timbers—2. Notes on Freijo (*Cordia goeldiana*) and Quaruba (*Vochysia* spp.). (1943)

No. 30. General Observations on the Design of Timber-drying Kilns. (1943)

No. 31. Foreign Timbers—3. Notes on Parana Pine (*Araucaria brasiliana*) and Louro (probably *Ocotea rubra*). (1943)

No. 32. Foreign Timbers—4. Notes on Peroba Rosa—(*Aspidosperma polyneuron*) and Mandioqueira (*Qualea* spp.). (1943)

No. 33. The Bending of Solid Timber. (1943)

No. 34. The Identification of Timbers. (1944)

No. 35. The Construction and Operation of Charcoal Kilns. (1944)

No. 36. Some Observations on Timber-drying Kilns and their Proper Use. (1944)

No. 37. Selecting Ash by Inspection. (1944)

No. 38. Termite-proofing of Timber for Use in the Tropics. (1944)

No. 39. Timber Decay and its Control. (1946)

No. 40. The Preparation of Wood for Microscopic Examination. (1946)

No. 41. Wood Waste as a Fuel. (1947)

* Obtainable gratis from the Laboratory (Princes Risborough, Aylesbury, Bucks.)

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Composite Wood, Veneers, Adhesives

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